

## COMPOSITIONS AND METHODS FOR TREATING CARDIOVASCULAR DISEASE

### CROSS REFERENCE TO RELATED APPLICATIONS

- 5           This application claims the benefit under 35 U.S.C. §119 of U.S. Provisional Application Serial Number 60/494,457, filed August 12, 2003, and United States Provisional Application Serial Number 60/406,418, filed August 28, 2002.

### FIELD OF THE INVENTION

- 10           Embodiments of the invention pertain to compositions and methods for treating cardiovascular disease by modulating inflammatory and immunoregulatory responses associated with cardiovascular disease.

### BACKGROUND

- 15           Cardiovascular disease encompasses a number of disorders that affect the muscle and/or blood vessels of the heart, peripheral blood vessels, muscles and various organs. It is established in the art that inflammatory and immunoregulatory processes are implicated in the pathogenesis of various forms of cardiovascular disease.

- For example, inflammatory immune responses have been shown to contribute to the pathogenesis of atherosclerosis. Elevated levels of C-reactive protein (CRP) have been associated with up to an 8.6 fold increase in the relative risk of symptomatic atherosclerosis (Biasucci, L., *et al.*, *Circulation* 1999, 99:855–860). Elevated levels of CRP also predict patients that are at elevated risk of myocardial infarction (MI) or stroke, and it has also been associated with poor prognosis in unstable angina (Vorchheimer, D., *et al.*, *JAMA* 2001, 286:2154–2156). Binding C1q CRP activates the classical complement pathway and may lead to direct myocardial damage, coronary smooth muscle or endothelial cell death and subsequent atherosclerotic plaque rupture (Agrawal, A., *et al.*, *J Immunol* 2001, 166:3998–4004). Furthermore, a recent study demonstrated that elevated levels of CRP are able to identify patients that die of sudden cardiac death 9 years prior to the event (Albert, C., *et al.*, *Circulation* 2002, 105:2595–9). These studies also imply that long-term inflammatory exposure and elevated CRP levels may contribute to the progression of acute coronary syndromes (Buffon, A., *et al.*, *NEJM* 2002, 347:55–7). Activation of inflammatory cells resident within an atherosclerotic plaque may elaborate enzymes capable of degrading extracellular matrix and lead to plaque rupture. Alternatively, these inflammatory cells may directly kill endothelial and smooth muscle cells. A number of studies have demonstrated that patients with unstable angina have peripheral T-cells that make enhanced levels of interferon gamma compared to patients with stable angina. Furthermore, there appears to be

clonal expansion of a CD4+CD28null T-cell population in these patients, which appear to be cytotoxic and can kill endothelial cells, an effect enhanced by CRP (Nakajima, T., *et al.*, *Circulation* 2002, 105:570-5).

Cytokines are critical regulators of the T-helper 1 (Th1) and Th2 T-cell responses.

5 The Th1 response results in pro-inflammatory cytokine release characterized by macrophage activation and, if unopposed, may result in tissue damage. The Th2 response results in a humoral immune response, B-cell activation and an allergic reaction (Neurath, M., *et al.*, *Nat Med* 2002, 8:567-73). A number of Th1 type cytokines including TNF, IL-6 and the chemokine MCP-1 are elevated in unstable angina (*AJC* 2001, 88(8A):10K-15K). Recently, 10 IL-18 has been found to be an independent marker for an adverse outcome in patients diagnosed with acute coronary syndrome (Blankenberg, S., *et al.*, *Circulation* 2002, 106:24-30). Elevated levels of IL-18 have also been found to correlate with ulcerated, symptomatic carotid artery lesions (Mallat, Z., *et al.*, *Circulation* 2001, 104:1598-603). In a mouse model of atherosclerotic plaque development in ApoE deficient mice, IL-18 was shown to accelerate 15 and enhance plaque formation, and IL-18 binding protein enhanced smooth muscle proliferation, which would promote plaque stability by increasing the thickness of the cap, and reduced the number of infiltrating macrophages and T-cells (Mallat, Z., *et al.*, *Circ Res.* 2001, 89:E41-5). Studies such as these establish a sound basis for implicating inflammatory and immunoregulatory responses in cardiovascular disease.

20 There is an unmet need in the art for treating cardiovascular disease by targeting the immunopathology of the disease. Embodiments of the present invention address such needs by providing compositions and methods for treating cardiovascular disease by modulating the inflammatory and immunoregulatory responses associated with cardiovascular disease.

### SUMMARY OF THE INVENTION

25 Embodiments of the present invention provide compositions and methods for the treatment of cardiovascular disease in a subject having cardiovascular disease, comprising administering an effective amount of one or more antagonists, such as IL-17 antagonists that inhibit the binding of IL-17 to the IL-17 receptor, as well as antagonists that prevent or diminish the activation of the IL-17 receptor; IL-18 antagonists that inhibit the binding of IL- 30 18 to the IL-18 receptor, as well as antagonists that prevent or diminish the activation of the IL-18 receptor; 4-1BB antagonists that inhibit the binding of 4-1BB ligand to 4-1BB, as well as antagonists that prevent or diminish the activation of 4-1BB ligand or 4-1BB; CD30 antagonists that inhibit the binding of CD30 ligand to CD30, as well as antagonists that prevent or diminish the activation of the CD30; OX40 antagonists that inhibit the binding of 35 OX40 ligand to OX40, as well as antagonists that prevent or diminish the activation of OX40; and/or CD39 alone or in any combination.

Additional embodiments are described in detail below.

### BRIEF DESCRIPTION OF THE FIGURES

Figures 1A and 1B depict IL-17 and IL-18 levels, respectively, in heart donor plasma in relation to three distinct groups: surviving donor recipients, donor recipients that died in less than 48 hrs. and unused donors with an ejection fraction (EF) of less than 30%.

Figure 2 shows relative abundance of IL-18 Receptor in patients having an ejection fraction (EF) of less than 30%, patients in end-stage failure (ESF) and patients having an ejection fraction of greater than 60% (i.e., normal myocardium).

Figures 3A through 3D show comparative levels of IL-17 and IL-18 plasma levels among patients in various stages of cardiomyopathy. Figures 3B and 3D further dissect the patient population into non-ischemic and ischemic groups.

Figure 4 illustrates the plasma levels of IL-17 (open bars) and IL-18 (closed bars) and 4-1BB (hatched bars) of control subjects or donors with favorable recipient outcome (group A) or adverse recipient outcome (group B) post-transplantation.

Figure 5 illustrates the effect of administering IL-17 on heart chamber dimensions over time.

Figures 6A and 6B depict IL-17 and IL-18 plasma levels in IFN- $\gamma$ <sup>-/-</sup> mice immunized with cardiac myosin peptide that induces an inflammatory myocarditis and cardiomyopathy.

Figures 7A through 7C: Figure 7A shows IL-17 levels in mice from the experimental autoimmune myocarditis (EAM) model, wherein mice having histologically demonstrated cardiopathology (animal B) had higher expression levels of IL-17 over negative controls (animals C and D). Figure 7B shows that IL-17 release from T-cells obtained from mice with EAM mice was approximately 25 fold higher compared to control mice. T-cells were isolated from animals immunized with cardiac myosin and exposed to antigen presenting cells fed myosin over antigen presenting cells not exposed to myosin. Figure 7C illustrates that T-cells from an animal immunized with cardiac myosin and having histological evidence of cardiopathology (animal B) released high levels of IL-17 in response to antigen-specific stimulation by peptide-pulsed antigen presenting cells.

Figures 8A and 8B show IL-18 levels and the ratio of IL-18 to IL-18 Binding Protein, respectively, in patients stratified into three patient groups: those having stable coronary artery disease (CAD), acute coronary syndrome (ACS) with cardiac troponin I (cTnI) plasma levels less than 0.4 ng/ml or acute coronary syndrome (ACS) with cardiac troponin I (cTnI) plasma levels greater than 0.4 ng/ml.

Figure 9 illustrates that 4-1BB plasma levels were significantly elevated in patients with heart failure compared to normal subjects thereby suggesting activation of this system in human heart failure.

Figure 10 represents a dose-response of Adriamycin® in wild type and 4-1BBL<sup>-/-</sup> knock out mice. At 22.5mg/kg and 25mg/kg, the percentage of Adriamycin®-induced

cardiac dysfunction was decreased in 4-1BBL<sup>-/-</sup>. At high dosage (30 mg/kg), no difference was observed between wild type and 4-1BBL<sup>-/-</sup> group.

Figure 11 is a graph showing 4-1BB activating antibody (M6) administered 3, 6, 9 days after Adriamycin® treatment. The onset of dysfunction was accelerated by M6 antibody, but the final penetrance was similar to control group.

### DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the invention provide compositions and methods for treating cardiovascular disease in a subject having cardiovascular disease comprising administering an effective amount of one or more IL-17 antagonists, IL-18 antagonists, 4-1BB antagonists, CD30 antagonists, OX40 antagonists and/or CD39, alone or in any combination.

Cardiovascular disease, as defined herein, encompasses diseases and disorders of the muscle and/or blood vessels of the heart, diseases and disorders of the vascular system, and/or diseases and disorders of organs and anatomical systems caused by the diseased condition of the heart and/or vasculature. Examples include, but are not limited to: inflammation of the heart and/or vasculature such as myocarditis, chronic autoimmune myocarditis, bacterial and viral myocarditis, as well as infective endocarditis; heart failure; congestive heart failure; chronic heart failure; cachexia of heart failure; cardiomyopathy, including non-ischemic (dilated cardiomyopathy; idiopathic dilated cardiomyopathy; cardiogenic shock, heart failure secondary to extracorporeal circulatory support ("post-pump syndrome"), heart failure following ischemia/reperfusion injury, brain death associated heart failure (as described in Owen et al., 1999 (Circulation. 1999 May 18;99(19):2565-70)); hypertrophic cardiomyopathy; restrictive cardiomyopathy; non-ischemic systemic hypertension; valvular disease; arrhythmogenic right ventricular cardiomyopathy) and ischemic (atherogenesis; atherosclerosis; arteriosclerosis; peripheral vascular disease; coronary artery disease; infarctions, including stroke, transient ischemic attacks and myocardial infarctions). Additional disease states encompassed by the definition of cardiovascular disease include: aneurysms; arteritis; angina; embolism; platelet-associated ischemic disorders; ischemia/reperfusion injury; restenosis; mitral and/or tricuspid regurgitation; mitral stenosis; silent myocardial ischemia; Raynaud's phenomena; thrombosis; deep venous thrombosis; pulmonary embolism; thrombotic microangiopathies including thrombotic thrombocytopenic purpura (TTP) and hemolytic uremic syndrome (HUS), essential thrombocythemia, disseminated intravascular coagulation (DIC), and thrombosis and coagulopathies associated with exposure to a foreign or injured tissue surfacethrombophlebitis; vasculitis, including Kawasaki's vasculitis; Takayasu's arteritis; veno-occlusive disease, giant cell arteritis, Wegener's granulomatosis; Schoenlein-Henoch purpura, as well as cardiovascular disease arising from periodontal infections by one or more oral pathogens, such as bacteria. The examples of cardiovascular disease provided above are merely illustrative and provided to aid



those of skill in the art to appreciate the scope of cardiovascular disease that may be treated using the compositions and methods described herein. Of course, other cardiovascular disease conditions may exist that can be treated using the inventive compositions and methods. Additional examples of cardiovascular disease and disorders associated with cardiovascular disease, as well as complications arising from the treatment of cardiovascular disease, are provided in the section below pertaining to therapeutic indications.

An “antagonist,” as defined herein, is a molecule that partially or completely blocks the binding of two cognates thereby inhibiting the downstream biological effects of the cognates’ interaction. For example, an antagonist may block the binding of a ligand to its receptor, which in turn reduces and/or prevents intracellular signalling via activating that receptor, which in turn reduces or prevents the downstream biological effects of activating that receptor, such as but not limited to, cell activation, proliferation, differentiation, cytokine release, up-regulation of genes, cell-surface expression of proteins, and the like.

Activating or activation of a receptor is defined herein as the engagement of one or more intracellular signaling pathway(s) and the transduction of intracellular signaling (i.e., signal transduction) in response to a molecule binding to a membrane-bound receptor, such as but not limited to, a receptor:ligand interaction.

“Signal transduction,” as used herein, is the relaying of a signal by conversion from one physical or chemical form to another. In cell biology, the process by which a cell converts an extracellular signal into a response.

Antagonists presented herein comprise soluble receptor molecules, ligands and/or binding proteins, including IL-17, IL-17 receptor (IL-17R), IL-18, IL-18 receptor (IL-18R), IL-18 binding protein (IL-18BP), CD30, CD30 ligand (CD30-L), 4-1BB, 4-1BB ligand (4-1BB-L), OX40, OX40 ligand (OX40-L) and CD39. Antagonists presented herein further comprise antibodies, fusion proteins and peptibodies directed against one or more of the following: IL-17, IL-17R, IL-18, IL-18R, CD30, CD30-L, 4-1BB, 4-1BB-L, OX40 and/or OX40-L. Antagonists presented herein further comprise small molecules, such as peptidomimetics and mimotopes, and the like, that antagonize the interaction between IL-17 and IL-17R, IL-18 and IL-18R, 4-1BB and 4-1BB-L, CD30 and CD30-L and/or OX40 and OX40-L. Additional antagonists comprise antisense oligonucleotides that specifically target and hybridize to the mRNA of IL-17, IL-17R, IL-18, IL-18R, CD30, CD30-L, 4-1BB, 4-1BB-L, OX40 and/or OX40-L thereby preventing gene translation of their respective proteins. Further embodiments comprise gene silencing by RNA-interference molecules tailored to silence expression of IL-17, IL-17R, IL-18, IL-18R, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40 and/or OX40-L. More specific definitions and examples of particular antagonists are provided in the sections below.

A “peptibody” refers to molecules comprising an Fc domain and at least one peptide. Such peptibodies may be multimers or dimers or fragments thereof, and they may be

derivatized. Peptibodies are described in greater detail in WO 99/25044 and WO 00/24782, which are incorporated herein by reference in their entirety. The peptide may be from the amino acid sequence of IL-17, IL-17 receptor (IL-17R), IL-18, IL-18 receptor (IL-18R), IL-18 binding protein (IL-18BP), CD30, CD30 ligand (CD30-L), 4-1BB, 4-1BB ligand (4-1BB-L), OX40, OX40 ligand (OX40-L) and/or CD39.

A "peptide," as used herein refers to molecules of 1 to 40 amino acids. Alternative embodiments comprise molecules of 5 to 20 amino acids. Exemplary peptides may comprise portions of the extracellular domain of naturally occurring molecules or comprise randomized sequences of IL-17, IL-17 receptor (IL-17R), IL-18, IL-18 receptor (IL-18R), IL-18 binding protein (IL-18BP), CD30, CD30 ligand (CD30-L), 4-1BB, 4-1BB ligand (4-1BB-L), OX40, OX40 ligand (OX40-L) and/or CD39.

The term "randomized" as used to refer to peptide sequences refers to fully random sequences (e.g., selected by phage display methods or RNA-peptide screening) and sequences in which one or more residues of a naturally occurring molecule is replaced by an amino acid residue not appearing in that position in the naturally occurring molecule. Exemplary methods for identifying peptide sequences include phage display, *E. coli* display, ribosome display, RNA-peptide screening, chemical screening, and the like.

The term "Fc domain" encompasses native Fc and Fc variant molecules and sequences as defined below. As with Fc variants and native Fc's, the term "Fc domain" includes molecules in monomeric or multimeric form, whether digested from whole antibody or produced by other means.

The term "native Fc" refers to molecule or sequence comprising the sequence of a non-antigen-binding fragment resulting from digestion of whole antibody, whether in monomeric or multimeric form. The original immunoglobulin source of the native Fc is preferably of human origin and may be any of the immunoglobulins, although IgG1 and IgG2 are preferred. Native Fc's are made up of monomeric polypeptides that may be linked into dimeric or multimeric forms by covalent (i.e., disulfide bonds) and non-covalent association. The number of intermolecular disulfide bonds between monomeric subunits of native Fc molecules ranges from 1 to 4 depending on class (e.g., IgG, IgA, IgE) or subclass (e.g., IgG1, IgG2, IgG3, IgA1, IgGA2). One example of a native Fc is a disulfide-bonded dimer resulting from papain digestion of an IgG (see Ellison *et al.* (1982), *Nucleic Acids Res.* 10: 4071-9). The term "native Fc" as used herein is generic to the monomeric, dimeric, and multimeric forms.

The term "Fc variant" refers to a molecule or sequence that is modified from a native Fc but still comprises a binding site for the salvage receptor, FcRn. International applications WO 97/34631 (published 25 September 1997) and WO 96/32478 describe exemplary Fc variants, as well as interaction with the salvage receptor, and are hereby incorporated by reference in their entirety. Thus, the term "Fc variant" comprises a molecule or sequence that

is humanized from a non-human native Fc. Furthermore, a native Fc comprises sites that may be removed because they provide structural features or biological activity that are not required for the fusion molecules of the present invention. Thus, the term "Fc variant" comprises a molecule or sequence that lacks one or more native Fc sites or residues that affect or are involved in (1) disulfide bond formation, (2) incompatibility with a selected host cell (3) N-terminal heterogeneity upon expression in a selected host cell, (4) glycosylation, (5) interaction with complement, (6) binding to an Fc receptor other than a salvage receptor, or (7) antibody-dependent cellular cytotoxicity (ADCC). Fc variants are described in further detail hereinafter.

A "peptidomimetic" is a peptide analog that displays more favorable pharmacological properties than their prototype native peptides, such as a) metabolic stability, b) good bioavailability, c) high receptor affinity and receptor selectivity, and d) minimal side effects. Designing peptidomimetics and methods of producing the same are known in the art (see for example, U.S.P.N. 6,407,059 and 6,420,118). Peptidomimetics may be derived from the binding site of the extracellular domain of IL-17, IL-17 receptor (IL-17R), IL-18, IL-18 receptor (IL-18R), IL-18 binding protein (IL-18BP), CD30, CD30 ligand (CD30-L), 4-1BB, 4-1BB ligand (4-1BB-L), OX40, OX40 ligand (OX40-L) and/or CD39. In alternative embodiments, a peptidomimetic comprises non-peptide compounds having the same three-dimensional structure as peptides derived from IL-17, IL-17 receptor (IL-17R), IL-18, IL-18 receptor (IL-18R), IL-18 binding protein (IL-18BP), CD30, CD30 ligand (CD30-L), 4-1BB, 4-1BB ligand (4-1BB-L), OX40, OX40 ligand (OX40-L) and/or CD39, or compounds in which part of a peptide from the molecules listed above is replaced by a non-peptide moiety having the same three-dimensional structure.

A "mimotope" is defined herein as peptide sequences that mimic binding sites on proteins (see, Partidos, CD, *et al.*, *Combinatorial Chem & High Throughput Screening*, 2002 5:15-27). A mimotope may have the capacity to mimic a conformationally-dependent binding site of a protein. The sequences of these mimotopes do not identify a continuous linear native sequence or necessarily occur in a naturally-occurring protein. Mimotopes and methods of production are taught in U.S.P.N. 5,877,155 and U.S.P.N. 5,998,577, which are incorporated by reference in their entireties.

The term "acidic residue" refers to amino acid residues in D- or L-form having sidechains comprising acidic groups. Exemplary acidic residues include D and E.

The term "amide residue" refers to amino acids in D- or L-form having sidechains comprising amide derivatives of acidic groups. Exemplary residues include N and Q.

The term "aromatic residue" refers to amino acid residues in D- or L-form having sidechains comprising aromatic groups. Exemplary aromatic residues include F, Y, and W.

The term "basic residue" refers to amino acid residues in D- or L-form having sidechains comprising basic groups. Exemplary basic residues include H, K, and R.

The term "hydrophilic residue" refers to amino acid residues in D- or L-form having sidechains comprising polar groups. Exemplary hydrophilic residues include C, S, T, N, and Q.

The term "nonfunctional residue" refers to amino acid residues in D- or L-form having sidechains that lack acidic, basic, or aromatic groups. Exemplary nonfunctional amino acid residues include M, G, A, V, I, L and norleucine (Nle).

The term "neutral hydrophobic residue" refers to amino acid residues in D- or L-form having sidechains that lack basic, acidic, or polar groups. Exemplary neutral hydrophobic amino acid residues include A, V, L, I, P, W, M, and F.

The term "polar hydrophobic residue" refers to amino acid residues in D- or L-form having sidechains comprising polar groups. Exemplary polar hydrophobic amino acid residues include T, G, S, Y, C, Q, and N.

The term "hydrophobic residue" refers to amino acid residues in D- or L-form having sidechains that lack basic or acidic groups. Exemplary hydrophobic amino acid residues include A, V, L, I, P, W, M, F, T, G, S, Y, C, Q, and N.

The term "subject" as used herein, refers to mammals. For example, mammals contemplated by the present invention include humans; primates; pets of all sorts, such as dogs, cats, etc.; domesticated animals, such as, sheep, cattle, goats, pigs, horses and the like; common laboratory animals, such as mice, rats, rabbits, guinea pigs, etc.; as well as captive animals, such as in a zoo or free wild animals. Throughout the specification, the term host is used interchangeably with subject.

As used herein the singular forms "a", "and", and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "an immunization" includes a plurality of such immunizations and reference to "the cell" includes reference to one or more cells and equivalents thereof known to those skilled in the art, and so forth. All technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs unless clearly indicated otherwise.

It is understood that the various embodiments of this invention are not limited to the particular methodology, protocols, cell lines, animal species or genera, constructs, and reagents described, as such may vary. It is also understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention which will be limited only by the appended claims.

## **I. IL-17, IL-18, 4-1BB, CD30 and OX40 ANTAGONISTS.**

### **A. IL-17 ANTAGONISTS**

Embodiments of the present invention provide compositions and methods for the treatment of cardiovascular disease comprising IL-17 antagonists. Studies presented herein

demonstrate that IL-17 and IL-18 are elevated in human patients having various forms and severity of cardiovascular disease. These studies demonstrate that circulating levels of IL-17 and/or IL-18 correlate with severity of cardiovascular disease. Furthermore, plasma levels of IL-17 and/or IL-18 are elevated in a cardiac myosin-induced myocarditis model and correlate with disease severity. Therefore, IL-17 and/or IL-18 are implicated in cardiovascular disease and provide a rational basis for treating cardiovascular disease by administering IL-17 and/or IL-18 antagonists, alone or in combination. In addition, IL-17 and/or IL-18 are prognostic indicators of cardiovascular disease and disease severity. IL-17 and/or IL-18 are also prognostic indicators of donor adequacy and post-transplant outcome. Therefore, further embodiments of the invention include assays for measuring IL-17 and/or IL-18 levels in subjects being screened for cardiovascular disease, cardiovascular disease severity, donor adequacy and post-transplant outcome.

An IL-17 antagonist is defined herein as an entity that is capable of reducing the effective amount of endogenous IL-17 in a subject, by either partially or completely blocking the interaction of IL-17 and the IL-17 receptor and thereby inhibiting IL-17-mediated signaling via membrane-bound IL-17 receptor, as well as partially or completely inhibiting the subsequent biological effects of activating the IL-17 receptor. An IL-17 antagonist may bind to IL-17 or to the IL-17 receptor.

Such IL-17 antagonists include, but are not limited to: soluble forms of IL-17 receptor; antibodies directed against IL-17 that specifically bind IL-17 and partially or completely inhibit binding of IL-17 to IL-17 receptor; antibodies, fusion proteins and/or peptibodies directed against IL-17 receptor that specifically bind IL-17 receptor and inhibit binding of IL-17 without themselves activating the IL-17 receptor; molecules that bind IL-17 or IL-17 receptor and inhibit the interaction thereof, such as IL-17 and/or IL-17 receptor peptidomimetics and/or mimotopes. As used herein, when reference is made to making IL-17 antagonists based on IL-17 or IL-17 receptor, it is understood that the terms IL-17 and IL-17 receptor also encompass fragments, variants, muteins, derivatives and fusion proteins thereof, as described in detail below.

Biological activity of IL-17 and IL-17R is defined herein as comprising binding of IL-17 to the IL-17R and activation of the IL-17R; proinflammatory effects; increased production of cytokines and chemokines, such as but not limited to, IL-6, IL-8, G-CSF, GM-CSF, MCP-1, Gro $\alpha$ , PGE<sub>2</sub>, as well as induction of costimulatory molecule ICAM. The IL-17:IL-17R interaction also has the biological activities of recruiting monocytes and neutrophils, up-regulation of iNOS, NO and COX-2; activation of all three subgroups of MAPKs (the p44 and p42 extracellular signal-regulated kinases ERK1 and ERK2), NF $\kappa$ B, stress-induced Jun NH<sub>2</sub>-terminal kinases (JNK1 and JNK2) and p38. Of course, it is understood that intermediate pathways that culminate in such biological activities are also included in the definition of biological activity for IL-17 and IL-17R.

IL-17 antagonists may comprise or be developed from IL-17 receptor polypeptide and/or polynucleotide sequences, as well as fragments, variants, muteins, derivatives and fusion proteins thereof. The isolation, cloning, preparation and characterization of human IL-17 receptor (referred to interchangeably as IL-17R or huIL-17R) are described in U.S.P.N. 5,869,286 and U.S.P.N. 6,072,033, which are incorporated herein by reference in their entirety. The full-length cDNA sequence for human IL-17R is provided in SEQ ID NO:3 and the corresponding amino acid sequence is provided in SEQ ID NO:4.

The human IL-17 receptor has an N-terminal signal peptide with a predicted cleavage site between amino acid 27 and 28. The signal peptide is followed by a 293 amino acid extracellular domain, a 21 amino acid transmembrane domain, and a 525 amino acid cytoplasmic tail. Soluble polypeptides are polypeptides that are capable of being secreted from the cells in which they are expressed. A secreted soluble polypeptide may be identified (and distinguished from its non-soluble membrane-bound counterparts) by separating intact cells which express the desired polypeptide from the culture medium, e.g., by centrifugation, and assaying the medium (supernatant) for the presence of the desired polypeptide. The presence of the desired polypeptide in the medium indicates that the polypeptide was secreted from the cells and thus is a soluble form of the polypeptide. The use of soluble forms of IL-17 receptor is advantageous for many applications. Purification of the polypeptides from recombinant host cells is facilitated, since the soluble polypeptides are secreted from the cells. Moreover, soluble polypeptides are generally more suitable than membrane-bound forms for parenteral administration and for many enzymatic procedures. Soluble forms of IL-17R that are useful in the methods of treating cardiovascular disease include the extracellular domain (residues 1-320 of SEQ ID NO:4 or residues 28-320 which excludes the signal peptide) or a fragment of the extracellular domain that has the properties of antagonizing or preventing binding of IL-17 to endogenous IL-17R. Soluble IL-17R also includes those polypeptides which include part of the transmembrane region, provided that the soluble IL-17R is capable of being secreted from a cell, and preferably retains the capacity to bind IL-17 and effectuate its biological effects.

Other forms of the IL-17R that are useful in the present invention include muteins and variants (also referred to as analogs), such as naturally occurring variants, that are substantially homologous to the native IL-17R of SEQ ID NO:4 and as described in U.S. Patent 6,072,033 that retain biological activity of IL-17R.

The invention further encompasses IL-17 antagonists derived from IL-17R polynucleotide sequences. Embodiments of the invention include full length nucleic acid molecules encoding soluble IL-17R as well as isolated fragments and oligonucleotides derived from the nucleotide sequence of SEQ ID NO:3. Such nucleic acid sequences may include nucleotides 178-1494 of SEQ ID NO:3 or a fragment thereof, and DNA and/or RNA sequences that hybridize to the coding region of the nucleotide sequence of SEQ ID NO:3, or

its complement, under conditions of moderate stringency, and which encode polypeptides or fragments thereof of the invention.

In other embodiments, IL-17 antagonists may comprise or be developed from IL-17 polynucleotide and/or polypeptide sequences. The full-length cDNA sequence for human IL-17 is provided in SEQ ID NO: 1 and the corresponding amino acid sequence is provided in SEQ ID NO: 2. Commercially available recombinant human IL-17 is also available, for example, from R&D Systems, Minneapolis, MN. IL-17 polypeptides, as well as biologically active fragments or derivatives thereof, may be used to generate antibodies that specifically bind to IL-17 and have the capacity of partially or completely blocking IL-17 binding to the IL-17 receptor.

In further embodiments, IL-17 antagonists are small molecules and polypeptide mimetics, such as but not limited to, peptidomimetics, peptibodies and/or mimotopes developed from the polypeptide sequence of IL-17 (SEQ ID NO:2) and/or IL-17R (SEQ ID NO:4). Polypeptide mimetics are peptide-containing molecules which mimic elements of protein secondary structure. Polypeptide mimetics, such as peptidomimetics and mimotopes, may be developed through techniques known in the art, such as combinatorial peptide libraries.

An IL-17 polypeptide mimetic based on the amino acid sequence of IL-17 will bind to IL-17R without activating the IL-17R and sterically hinder binding of endogenous IL-17. Conversely, an IL-17R polypeptide mimetic based on the amino acid sequence of IL-17R will bind to IL-17 and sterically hinder IL-17 from binding to endogenous IL-17R. IL-17 peptide mimetics may be used to antagonize IL-17 in a subject and thereby reduce the proinflammatory effects of IL-17. As such, IL-17 polypeptide mimetics may be used to treat inflammatory and/or immunoregulatory processes associated with cardiovascular disease.

Other forms of the IL-17 that are useful in the present invention include muteins and variants (also referred to as analogs), such as naturally occurring variants, that are substantially homologous to the native IL-17 of SEQ ID NO:2 that retain biological activity of IL-17. For example, IL-17 homologues B, C, D, E and F. This invention additionally provides for the use of IL-17 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease. This invention further provides for the use of polynucleotides encoding IL-17 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease.

## **B. IL-18 ANTAGONISTS**

Embodiments of the present invention provide compositions and methods for the treatment of cardiovascular disease comprising IL-18 antagonists. An IL-18 antagonist is defined herein as an entity that is capable of reducing the effective amount of endogenous IL-18, by either partially or completely blocking the interaction of IL-18 and the IL-18R and

thereby inhibiting IL-18-mediated signaling via membrane-bound IL-18R, as well as partially or completely inhibiting the subsequent biological effects of activating the IL-18 receptor. An IL-18 antagonist may bind to IL-18 or to the IL-18R. Antagonists derived from the IL-18R and IL-18 Binding Protein (e.g. soluble forms that bind IL-18) compete for IL-18 with  
 5 IL-18R on the cell surface, thus inhibiting IL-18 from binding to cells, thereby preventing IL-18 from manifesting its biological activities.

IL-18:IL-18R biological activity, is defined herein as including, but is not limited to, binding of IL-18 to the IL-18R and activation of the IL-18R; regulation of innate and acquired immune responses; proinflammatory effects; induction of T-lymphocyte helper cell  
 10 type 1 responses (Th1); enhance cell-mediated cytotoxicity; IFN- $\gamma$  induction; enhanced production of GM-CSF and IL-2; potentiation of anti-CD3 induced T-cell proliferation; increased Fas-mediated killing by natural killer cells (NK cells) and CD4+ Th1 cells; increased apoptotic death via the Fas-FasL pathway; up-regulation of FasL expression; induction of T-lymphocyte helper cell type 2 responses (Th2) in T-cells and NK cells;  
 15 stimulation of basophils and mast cells to produce Th2 cytokines and histamine; induction of IgE production

Such IL-18 antagonists include, but are not limited to: soluble forms of IL-18R; IL-18 Binding Protein; antibodies directed against IL-18 that specifically bind IL-18 and partially or completely inhibit binding of IL-18 to IL-18R; antibodies, fusion proteins and/or peptobodies  
 20 directed against IL-18R that specifically bind IL-18R and inhibit receptor binding of IL-18 without themselves transducing a signal via IL-18R; small molecules that bind IL-18 or IL-18R that inhibit the interaction thereof, such as IL-18 and/or IL-18R peptidomimetics and/or mimotopes. As used herein, when reference is made to making IL-18 antagonists based on IL-18, IL-18 Binding Protein or IL-18 receptor, it is understood that the terms IL-18, IL-18  
 25 Binding Protein and IL-18 receptor also encompass fragments, variants, muteins, derivatives and fusion proteins thereof, as described in detail below.

The isolation, cloning, preparation and characterization of human IL-18 receptor (referred to interchangeably as IL-18R or huIL-18R) are described in U.S.P.N. 6,087,116 and U.S. Patent Application Serial No. 09/621,502 (PCT Publication WO 99/37772), which are  
 30 incorporated herein by reference in their entirety. The IL-18 receptor is a heterodimeric protein containing an IL-18 binding subunit termed IL-1Rrp1, and an accessory subunit termed AcPL. Although the IL-1Rrp1 subunit alone will bind IL-18, its affinity for IL-18 is increased dramatically when present in a heterodimeric complex with the AcPL subunit.

The IL-1Rrp1 polynucleotide sequence and corresponding amino acid sequence that it  
 35 encodes are provided as SEQ ID NO:5 and SEQ ID NO:6, respectively. The soluble extracellular portion of the IL-1Rrp1 subunit that binds IL-18 is represented by amino acids 20 to 329 of SEQ ID NO:6; cleavage of the signal sequence occurs just after amino acid residue 19 of SEQ ID NO:6. However, fragments as small as amino acid residues 20 to 123



and amino acid residues 20 to 226 of SEQ ID NO:6 have been reported to bind IL-18 and can also be used. The IL-1Rrp1 polypeptide is also described in U.S. Patent No. 5,776,731, incorporated in its entirety by reference herein.

The AcPL polynucleotide sequence and the amino acid sequence that it encodes are provided herein as SEQ ID NO:7 and SEQ ID NO:8, respectively. The mature extracellular domain of AcPL consists of amino acids 15 to 356 of SEQ ID NO:8; cleavage of the signal sequence occurs just after amino acid residue 14 of SEQ ID NO:8. The AcPL polypeptide, and soluble extracellular fragments thereof, are also described in U.S. Patent Application Serial No. 09/621,502 (PCT Publication WO 99/37772), incorporated herein by reference in its entirety.

One embodiment of a soluble form of an IL-18 receptor for use in the methods of the present invention comprises amino acids 1-329 sequence of SEQ ID NO:6; alternative embodiments of a soluble form of an IL-18 receptor comprises amino acids 20-329 after cleavage of the signal sequence of SEQ ID NO:6. A further embodiment of a soluble form of IL-18 receptor is a heterodimeric receptor that includes at least amino acid residues 20-123, 20-226 or 20-329 of SEQ ID NO:6 (the IL-1Rrp1 subunit), and at least amino acids 15-340 of SEQ ID NO:8 (the AcPL subunit), in a covalent or non-covalent association.

Additional IL-18 antagonists comprise the IL-18 Binding Protein. PCT Publication WO 99/09063 describes the IL-18 binding protein, including useful soluble fragments thereof. One embodiment of a human IL-18 Binding Protein is the "a" isoform having the polynucleotide sequence of SEQ ID NO:9 and the corresponding amino acid sequence of SEQ ID NO:10. Of course, other IL-18 Binding Protein isoforms that are antagonistic to IL-18 binding to IL-18R may be used, such as the b, c and d isoforms. The polynucleotide and amino acid sequences for the b, c and d isoforms are known in the art and readily available (see for example, Kim, S.-H., et al., *PNAS* 97:3 1190-1195 (2000)). A particularly useful form of the IL-18 binding protein is a fusion with an Fc domain of an antibody. The amino acid sequence of an example of such a fusion protein, termed IL-18BP-Fc herein, is presented in SEQ ID NO:11. This 422 amino acid protein, when expressed in a mammalian cell, will be secreted; the mature secreted form of the protein contains amino acid residues 29-422. Of these residues, amino acid residues 29-192 represent the IL-18 binding protein portion of the molecule, and amino acid residues 193-422 represent the Fc portion of the molecule. The Fc region facilitates purification and dimerization of the fusion polypeptide.

IL-18 antagonists may also comprise or be developed from IL-18 polynucleotide and/or polypeptide sequences. Human IL-18 has been recombinantly produced from a cloned cDNA, as described in U.S. Patent No. 5,891,663 and cloned genomic DNA, as disclosed in U.S. Patent No. 6,060,283, which are incorporated by reference in their entirety. The full-length cDNA sequence is provided in SEQ ID NO:12 with the corresponding amino acid sequence in SEQ ID NO:13. The amino acid sequence for ICE-processed human IL-18

provided in SEQ ID NO:14. Commercially available recombinant human IL-18 is available, for example, from R&D Systems, Minneapolis, MN. IL-18 polypeptides as well as biologically active fragments or derivatives thereof may be used to generate antibodies that specifically bind to IL-18 and have the capacity of partially or completely blocking IL-18 binding to the IL-18 receptor.

In one embodiment, IL-18 antagonists are polypeptide mimetics, such as, but not limited to peptidomimetics, peptibodies and/or mimotopes developed from the polypeptide sequence of IL-18 (SEQ ID NO:13 and/or 14). Polypeptide mimetics may be developed through techniques known in the art, such as combinatorial peptide libraries. Polypeptide mimetics are peptide-containing molecules which mimic elements of protein secondary structure. An IL-18 polypeptide mimetic based on the amino acid sequence of IL-18 will bind to IL-18 receptor without activating the IL-18 receptor and sterically hinder binding of endogenous IL-18. IL-18 peptide mimetics may be used to antagonize IL-18 in a subject and thereby reduce the proinflammatory effects of IL-18. As such, IL-18 polypeptide mimetics may be used to treat inflammatory and/or immunoregulatory processes associated with cardiovascular disease.

Other embodiments of IL-18, IL-18 receptor and IL-18 Binding Protein that may be used as IL-18 antagonists include muteins and variants (as described in greater detail below), such as naturally occurring variants, that are substantially homologous to the native IL-18 of SEQ ID NO:13 and/or 14, IL-18 receptor of SEQ ID NOs:6 and 8, and IL-18 Binding Protein of SEQ ID NO:10 that retain biological activity. Biological activity, in this instance, is the capacity to bind its cognate partner.

This invention additionally provides for the use of IL-18 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease. This invention further provides for the use of polynucleotides encoding IL-18 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease.

### C. 4-1BB ANTAGONISTS

Further embodiments of the present invention provide compositions and methods for the treatment of cardiovascular disease comprising 4-1BB antagonists.

Examples 7 and 8 describe studies demonstrating a role for the 4-1BB/4-1BBL immune co-stimulatory pathway in Adriamycin®-induced cardiomyopathy, as well as demonstrating a novel cardiac expression pattern of 4-1BB and implicating apoptosis as a mechanism of co-stimulatory contribution to Adriamycin®-induced cardiomyopathy. More specifically, 4-1BBL deficient mice and 4-1BBL decoy receptor-treated mice conferred partial resistance to adriamycin induced cardiac damage, whereas 4-1BB activating antibody accelerated onset of damage, implying the contribution of 4-1BB to Adriamycin® effects in heart. Apoptosis, measured by TUNEL, sub-G1 DNA and activated caspase-3, was increased

in Adriamycin®-treated wild type myocardium, but reduced in 4-1BBL<sup>-/-</sup>. Phosphorylation of Akt was selectively suppressed by Adriamycin®, but maintained by loss of 4-1BBL, indicating the modulation of apoptosis by co-stimulatory pathway in heart is possibly through Akt, but not Jnk and p38 signaling. The consistency of decreased index of apoptosis and the improved cardiac function in 4-1BBL<sup>-/-</sup> suggests apoptosis play a pivotal role in Adriamycin®-induced cardiac deficiency.

A single retroorbital (RO) injection of adriamycin (22.5 mg/kg) leads to progressive cardiac dysfunction without evidence of inflammatory infiltration. In this model of non-inflammatory, drug-induced cardiomyopathy, 4-1BBL<sup>-/-</sup> mice have substantially improved cardiac function by echocardiography. Furthermore, m4-1BB Fc (a soluble decoy receptor for 4-1BBL) reduced ADR cardiac dysfunction, while an agonistic antibody to 4-1BB (M6) accelerated and exacerbated cardiac dysfunction. While no inflammatory infiltrate is observed in this ADR-cardiomyopathy, we found expression of 4-1BB induced on 1-5% of cardiac interstitial cells within 2 days after ADR. Cardiac apoptosis, measured by TUNEL and sub-G1 DNA, is increased 3 days after ADR (45mg/kg), concomitant with the increased expression of 4-1BB on interstitial cells. Chronic ongoing apoptosis, determined 5 weeks after ADR challenge when cardiac dysfunction is maximal in wild type but largely absent in 4-1BBL<sup>-/-</sup> mice, was lower in 4-1BBL<sup>-/-</sup> mice (1.5-fold vs baseline), compared to WT mice (4 fold). In a separate study, caspase 3 activation, determined by Western blot, was increased at 48 to 72 hrs post-ADR (45mg/kg). In contrast, ADR did not induce caspase 3 cleavage in 4-1BBL<sup>-/-</sup> myocardium. Determined by western blot, adriamycin reduced phosphorylation of Akt in wild type but not 4-1BBL<sup>-/-</sup> hearts. Phosphorylation of JNK and p38 was not impacted by ADR. In summary, 4-1BB/4-1BBL immune co-stimulatory pathway contributes to ADR-induced cardiomyopathy, possibly, through modulation of Akt signaling to regulate apoptosis in the heart.

A 4-1BB antagonist is defined herein as an entity that is capable of reducing the effective amount of available endogenous 4-1BB and/or 4-1BB ligand (4-1BB-L), by either partially or completely blocking the interaction of 4-1BB and 4-1BB-L and thereby inhibiting 4-1BB-mediated signaling via 4-1BB-L and 4-1BB-L-mediated signaling via 4-1BB, as well as the subsequent biological effects of activating 4-1BB and/or 4-1BB-L. In other words, because the 4-1BB:4-1BB-L interaction exhibits bi-directional signalling, a 4-1BB antagonist may bind either 4-1BB or 4-1BB-L so long as the antagonist does not itself activate 4-1BB or 4-1BB-L. Such 4-1BB antagonists include, but are not limited to: soluble forms of 4-1BB; antibodies, fusion proteins and/or peptibodies directed against 4-1BB that specifically bind 4-1BB and partially or completely inhibit binding of 4-1BB to 4-1BB-L; antibodies, fusion proteins and/or peptibodies directed against 4-1BB that specifically bind 4-1BB and inhibit binding of 4-1BB-L without themselves transducing a signal via 4-1BB; molecules that bind 4-1BB or 4-1BB-L and inhibit the interaction thereof, such as 4-1BB and/or 4-1BB-L small

molecules, peptidomimetics and/or mimotopes, and/or polypeptides comprising all or portions of 4-1BB or 4-1BB-L or modified variants thereof, including genetically-modified muteins, multimeric forms and sustained-release formulations thereof.

4-1BB:4-1BB-L biological activity, is defined herein as including, but is not limited to, binding of 4-1BB-L to 4-1BB and activation of one or both of 4-1BB and 4-1BB-L; costimulatory activity on T lymphocytes; activation and differentiation of CD4+ and CD8+ cells; signal transduction through TRAF pathways (TRAF1, TRAF2 and TRAF3) and activation of NF $\kappa$ B and AP-1; inhibition of activation-induced cell death; facilitation of B-cell proliferation and monocyte activation; up-regulation of cytokines including, but not limited to, IL-6, IL-8 and TNF- $\alpha$ ; up-regulation of adhesion molecules, such as ICAM; down-regulation of Fc $\gamma$ RIII; production of M-CSF in monocytes; monocyte proliferation; and inhibition of T-cell proliferation induced by anti-CD3 antibodies.

4-1BB antagonists may comprise or be developed from 4-1BB-L polypeptide and polynucleotide sequences. The isolation, cloning, preparation and characterization of human 4-1BB-L (referred to interchangeably as hu4-1BB-L) is described in U.S.P.N. 5,674,704, which is incorporated herein by reference in its entirety. 4-1BB-L refers to a genus of mammalian polypeptides that are capable of binding 4-1BB. 4-1BB-L is a type II extracellular membrane polypeptide with an intracellular (cytoplasmic) domain at the N-terminus of the polypeptide (amino acids 1-25 of SEQ ID NO:15), followed by a transmembrane region polypeptide (amino acids 26-48 of SEQ ID NO:15), and an extracellular (receptor-binding) domain at the C-terminus of the polypeptide (amino acids 49-254 of SEQ ID NO:15). Soluble 4-1BB-L polypeptides may be derived from the extracellular domain, as described below. The full-length cDNA sequence for human 4-1BB-L is provided in SEQ ID NO:14 and the corresponding amino acid sequence is provided in SEQ ID NO:15. The human 4-1BB-L protein comprises a cytoplasmic domain (amino acids 1-25), a transmembrane region (amino acids 26-48), and an extracellular domain (amino acids 49-254 of SEQ ID NO:15).

In addition, 4-1BB antagonists may comprise or be developed from 4-1BB polypeptide and polynucleotide sequences. The polynucleotide sequence of a human 4-1BB cDNA and the amino acid sequence encoded thereby are presented in SEQ ID NO:17 and SEQ ID NO:18, respectively. The human 4-1BB protein comprises an N-terminal signal sequence (amino acids -23 to -1 of SEQ ID NO:18), an extracellular domain comprising amino acids 1-163, a transmembrane region comprising amino acids 164-190, and a cytoplasmic domain comprising amino acids 191-232.

Soluble forms of 4-1BB-L and 4-1BB proteins are provided herein. Soluble 4-1BB-L or 4-1BB polypeptides comprise all or part of the extracellular domain but lack the transmembrane region that would cause retention of the polypeptide on a cell membrane. Since the 4-1BB-L protein lacks a signal peptide, a heterologous signal peptide may be fused

to the N-terminus of soluble 4-1BB-L polypeptides to promote secretion thereof. The signal peptide is cleaved from the protein upon secretion from the host cell. Soluble 4-1BB-L polypeptides include fragments that retain the ability to bind 4-1BB, such as truncated polypeptides of the extracellular domain, and soluble 4-1BB polypeptides include fragments that retain the ability to bind 4-1BB-L, such as truncated polypeptides of the extracellular domain 4-1BB. In alternative embodiments, the soluble proteins may include part of the transmembrane region or part of the cytoplasmic domain, provided that the protein is capable of being secreted rather than retained on the cell surface. Examples of soluble polypeptides include those comprising the entire extracellular domain. Specific examples include, but are not limited to a soluble human 4-1BB-L polypeptide comprising amino acids 49-254 of SEQ ID NO:16 and a soluble human 4-1BB polypeptide comprising amino acids 1-163 of SEQ ID NO:18.

In one embodiment, 4-1BB antagonists are polypeptide mimetics, such as but not limited to, peptidomimetics, peptibodies and/or mimotopes developed from the polypeptide sequence of 4-1BB-L (SEQ ID NO:16) and 4-1BB (SEQ ID NO:18). Polypeptide mimetics may be developed through techniques known in the art, such as combinatorial peptide libraries. Polypeptide mimetics are peptide-containing molecules which mimic elements of protein secondary structure. A 4-1BB polypeptide mimetic based on the amino acid sequence of 4-1BB will bind to 4-1BB-L without activating 4-1BB-L and sterically hinder binding of endogenous 4-1BB. Similarly, a 4-1BB-L polypeptide mimetic based on the amino acid sequence of 4-1BB-L will bind to 4-1BB without activating 4-1BB and sterically hinder binding of endogenous 4-1BB-L. 4-1BB and 4-1BB-L peptide mimetics may be used to antagonize their respective cognates in a subject and thereby reduce the proinflammatory effects of the 4-1BB/4-1BB-L interaction. As such, 4-1BB antagonists in the form of polypeptide mimetics may be used to treat inflammatory and/or immunoregulatory processes associated with cardiovascular disease.

Other embodiments of 4-1BB and 4-1BB-L that may be used as 4-1BB antagonists include muteins and variants (as described in greater detail below), such as naturally occurring variants, that are substantially homologous to the native 4-1BB-L (SEQ ID NO:16) and 4-1BB (SEQ ID NO:18) polypeptide sequences that retain biological activity. Biological activity, in this instance, is the capacity to bind its cognate partner.

This invention additionally provides for the use of 4-1BB antagonists in the manufacture of a medicament for the treatment of cardiovascular disease. This invention further provides for the use of polynucleotides encoding 4-1BB antagonists in the manufacture of a medicament for the treatment of cardiovascular disease.

#### D. CD30 ANTAGONISTS

Further embodiments of the present invention provide compositions and methods for the treatment of cardiovascular disease comprising one or more CD30 antagonists. A CD30 antagonist is defined herein as an entity that is capable of reducing the effective amount of endogenous CD30 ligand (CD30-L), by either partially or completely blocking the interaction of CD30-L and CD30 and thereby inhibiting CD30-mediated signaling via membrane-bound CD30, as well as partially or completely inhibiting the subsequent biological activity of activating CD30. A CD30 antagonist may bind to either CD30-L or CD30.

The biological activity of CD30:CD30-L includes, but is not limited to, binding of CD30-L to CD30 and activation of CD30; intracellular activation of NF- $\kappa$ B, cytokine release and/or proliferation of CD30+ cells; proliferation of T-cells in the presence of an anti-CD3 co-stimulus.

Such CD30 antagonists include, but are not limited to: soluble forms of CD30-L and CD30; fragments of CD30-L that bind CD30 and inhibit binding of CD30-L without activating membrane-bound CD30; fragments of CD30 that bind CD30-L and inhibit binding of CD30-L to CD30; antibodies, fusion proteins and/or peptibodies directed against CD30-L that specifically bind CD30-L and partially or completely inhibit binding of CD30-L to CD30; antibodies, fusion proteins and/or peptibodies directed against CD30 that specifically bind CD30 and inhibit binding of CD30-L without themselves activating the CD30; small molecules that bind CD30-L or CD30 and inhibit the interaction thereof, such as CD30-L and/or CD30 peptidomimetics and/or mimotopes. As used herein, when reference is made to CD30 antagonists based on CD30-L or CD30, it is understood that the terms CD30-L and CD30 also encompass fragments, variants, muteins, derivatives and fusion proteins thereof, as described in detail below.

CD30 antagonists may comprise or be developed from CD30-L polynucleotide and polypeptide sequences. The isolation, cloning, preparation and characterization of human CD30-L is described in U.S.P.N. 5,480,981, which is incorporated herein by reference in its entirety. As mentioned above, embodiments of the present invention include anti-CD30-L antibodies as CD30 antagonists. Examples of antibodies that are directed against CD30-L that may be used to treat cardiovascular disease are described in U.S.P.N. 5,677,430, which is incorporated by reference in its entirety.

The term "CD30-L" as used herein refers to a genus of polypeptides which are capable of binding CD30. As used herein, the term "CD30-L" includes membrane-bound proteins (comprising a cytoplasmic domain, a transmembrane region, and an extracellular domain) as well as truncated proteins that retain the CD30-binding property. Such truncated proteins include, for example, soluble CD30-L comprising only the extracellular (receptor binding) domain. CD30-L is expressed on monocytes/macrophages, granulocytes, a subset of

B cells and on activated but not resting T cells. By binding with cell-surface CD30, CD30-L can induce murine B cell differentiation and can induce the proliferation of activated T cells in the presence of an anti-CD3 co-stimulus (see, for example, Smith et al., *Cell* 73:1349-1360 (1993)). Moreover, CD30-L exhibits "reverse signaling," that is, the cell surface CD30-L that is expressed on neutrophils and peripheral blood T cells can be activated by cross-linking to stimulate metabolic activities in those cells (Wiley et al., *J Immunol* 157: 3235-39 (1996)).

CD30-L proteins of the present invention include, but are not limited to, human CD30-L comprising amino acids 1-215 of SEQ ID NO:20 or 1-234 of SEQ ID NO:22; and proteins that comprise N-terminal, C-terminal, or internal truncations of the foregoing sequences, but retain the desired biological activity. Examples include human CD30-L proteins comprising amino acids y to 234 of SEQ ID NO:22 wherein y is 1-19 (i.e., the N-terminal amino acid is any one of amino acids 1-19 of SEQ ID NO:22, and amino acid 234 is the C-terminal amino acid. Such proteins, truncated at the N-terminus, are capable of binding CD30.

Alternative embodiments provide soluble CD30-L polypeptides. Soluble CD30-L polypeptides comprise all or part of the extracellular domain of a native CD30-L but lack the transmembrane region that would cause retention of the polypeptide on a cell membrane. Since the CD30-L protein lacks a signal peptide, a heterologous signal peptide may be fused to the N-terminus of a soluble CD30-L protein to promote secretion thereof. The signal peptide is cleaved from the CD30-L protein upon secretion from the host cell. The soluble CD30-L polypeptides retain the ability to bind the CD30 receptor. Soluble CD30-L may also include part of the transmembrane region or part of the cytoplasmic domain or other sequences, provided that the soluble CD30-L protein is capable of being secreted.

Examples of soluble CD30-L polypeptides include those comprising the entire extracellular domain of a native CD30-L protein or a fragment of said extracellular domain that is capable of binding CD30. One such soluble CD30-L polypeptides comprise amino acids z to 215 (Asp) of the human CD30-L sequence of SEQ ID NO:20, wherein z is 44, 45, 46, or 47. In other words, the N-terminal amino acid of the soluble human CD30-L is selected from the amino acids in positions 44-47 of SEQ ID NO:20. DNA sequences encoding such soluble human CD30-L polypeptides include, but are not limited to, DNA sequences comprising a nucleotide sequence selected from the group consisting of nucleotides 130-645, 133-645, 136-645, and 139-645 of SEQ ID NO:19. Such sequences encode polypeptides comprising amino acids 44-215, 45-215, 46-215, and 47-215, respectively, of SEQ ID NO:20. Production of one such soluble human CD30-L protein, in the form of a fusion protein comprising amino acids 47-215 of SEQ ID NO:20 and an antibody Fc polypeptide, is illustrated in Example 11 of U.S.P.N. 5,480,981.

CD30 antagonists may comprise or be developed from CD30 polypeptide and/or polynucleotide sequences. Cloning and expression of a gene encoding CD30 has been

reported and CD30 has been characterized as a transmembrane protein that possesses substantial homology to the nerve growth factor receptor superfamily (Durkop *et al.*, *Cell* 1992, 68:421). The CD30 polynucleotide sequence reported in Durkop *et al. supra* is presented in SEQ ID NO:23, and the amino acid sequence encoded thereby is presented in  
5 SEQ ID NO:24. The extracellular portion of human CD30 corresponds to amino acids 1-390, or if the signal peptide is removed, to amino acids 19-390 of SEQ ID NO:24. The transmembrane region comprises amino acids 391-407 of SEQ ID NO:24. The phrase "soluble CD30" (sCD30) refers to soluble molecules that comprise all or part of the extracellular domain of the CD30 protein, and that retain the capacity to bind specifically  
10 with CD30-L. The polynucleotide and polypeptide sequences, as well as a description of how to make a CD30-Fc fusion protein, which may serve as a CD30 antagonist for the treatment of cardiovascular disease, is described in detail in U.S.P.N. 5,480,981, which is incorporated herein by reference in its entirety.

In further embodiments, CD30 antagonists are polypeptide mimetics, such as, but not  
15 limited to peptidomimetics, peptibodies and/or mimotopes developed from the polypeptide sequence of CD30-L (SEQ ID NOs:20 and/or 22) and/or CD30 (SEQ ID NO:24). Polypeptide mimetics may be developed through techniques known in the art, such as combinatorial peptide libraries. Polypeptide mimetics are peptide-containing molecules which mimic elements of protein secondary structure. A CD30-L polypeptide mimetic based  
20 on the amino acid sequence of CD30-L will bind to CD30 without activating CD30 and sterically hinder binding of endogenous CD30-L. A CD30 receptor polypeptide mimetic based on the amino acid sequence of CD30 receptor will bind to CD30-L and sterically hinder binding of endogenous CD30-L to CD30. CD30-L and CD30 peptide mimetics can be used to antagonize CD30-L binding to CD30 in a subject and thereby reduce the  
25 proinflammatory effects of CD30-L. As such, CD30 antagonists in the form of polypeptide mimetics may be used to treat inflammatory and/or immunoregulatory processes associated with cardiovascular disease.

Other forms of CD30-L and CD30 that are useful in the present invention include muteins and variants (also referred to as analogs), such as naturally occurring variants, that  
30 are substantially homologous to the native CD30-L (SEQ ID NOs:20 and/or 22) or CD30 (SEQ ID NO:24) polypeptide sequences and as described in U.S.P.N. 5,480,981 that retain biological activity.

This invention additionally provides for the use of CD30 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease. This invention  
35 further provides for the use of polynucleotides encoding CD30 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease.

#### **E. OX40 ANTAGONISTS**



Further embodiments of the present invention provide compositions and methods for the treatment of cardiovascular disease comprising one or more OX40 antagonists. A OX40 antagonist is defined herein as an entity that is capable of reducing the effective amount of endogenous OX40 ligand (OX40-L), by either partially or completely blocking the interaction of OX40-L and OX40 and thereby inhibiting OX40-mediated signaling via membrane-bound OX40, as well as partially or completely inhibiting the subsequent biological activity of activating OX40. A OX40 antagonist may bind to either OX40-L or OX40.

OX40:OX40-L biological activity, is defined herein as including, but is not limited to, binding of OX40-L to OX40 and activation of OX40; costimulatory activity on T lymphocytes; cytokine production, including IL-4; promoting the survival and proliferation of CD4+ T cells; prolongation of immune responses; enhancing effector and memory-effector T cell function by upregulating IL-2 production and increasing the life-span of effector T cells; and, enhanced tumor-specific immunity.

Such OX40 antagonists include, but are not limited to: soluble forms of OX40-L and OX40; fragments of OX40-L that bind OX40 and inhibit binding of OX40-L without activating membrane-bound OX40; fragments of OX40 that bind OX40-L and inhibit binding of OX40-L to OX40; antibodies, fusion proteins and/or peptibodies directed against OX40-L that specifically bind OX40-L and partially or completely inhibit binding of OX40-L to OX40; antibodies, fusion proteins and/or peptibodies directed against OX40 that specifically bind OX40 and inhibit binding of OX40-L without themselves activating the OX40; small molecules that bind OX40-L or OX40 and inhibit the interaction thereof, such as OX40-L and/or OX40 peptidomimetics and/or mimotopes. As used herein, when reference is made to OX40 antagonists based on OX40-L or OX40, it is understood that the terms OX40-L and OX40 also encompass fragments, variants, muteins, derivatives and fusion proteins thereof, as described in detail below.

OX40 antagonists may comprise or be developed from OX40 polynucleotide and polypeptide sequences. The OX-40 receptor, also referred to as OX40, ACT-4 and ACT35, is a protein expressed on the surface of antigen-activated mammalian CD4+ T-cells. DNA sequences encoding mouse, rat and human OX-40 receptor homologs have been cloned and sequenced (see, Mallet, *et al.*, *EMBO*, 9:1063-1068 (1990); Calderhead, *et al.*, *J Immunol*, 151:5261-5271 (1993); Latza, *et al.*, *Eur. J. Immunol.* 24:677-683 (1994); and WO 95/12673). The isolation, cloning, and characterization of human OX40 is described in U.S.P.N. 5,821,332 and 6,277,962 B1, which are incorporated herein by reference in their entirety. As mentioned above, embodiments of the present invention include anti-OX40 antibodies as OX40 antagonists. Examples of antibodies that are directed against OX40 are described in U.S.P.N. 5,821,332 and 6,277,962 B1.

OX40 proteins of the present invention include, but are not limited to, human OX40 comprising amino acids 1-277 of SEQ ID NO:28; and proteins that comprise N-terminal, C-terminal, or internal truncations of the foregoing sequences, but retain the desired biological activity. DNA sequences encoding such human OX40 polypeptides include, but are not limited to, DNA sequences comprising the nucleotide sequence of SEQ ID NO:27.

Alternative embodiments provide soluble OX40 polypeptides. Soluble OX40 polypeptides comprise all or part of the extracellular domain of a native OX40 but lack the transmembrane region that would cause retention of the polypeptide on a cell membrane. The soluble OX40 polypeptides retain the ability to bind the OX40-L. Soluble OX40 polypeptides may also include part of the transmembrane region or part of the cytoplasmic domain or other sequences, provided that the soluble OX40 protein is capable of being secreted. The putative signal sequence is from amino acids 1-22 or 1-24 and the extracellular domain spanning amino acids 23-212 or 24-212 or 24-212 and the transmembrane sequence spanning amino acids 213-240 of SEQ ID NO:28.

Examples of soluble OX40 polypeptides include those comprising the entire extracellular domain of a native OX40 protein or a fragment of said extracellular domain that is capable of binding OX40-L. One such soluble OX40-L polypeptides comprise amino acids z to 213 SEQ ID NO:28, wherein z is 22, 23, 24, or 25. In other words, the N-terminal amino acid of the soluble human OX40-L is selected from the amino acids in positions 22-25 of SEQ ID NO:28.

OX40 antagonists may comprise or be developed from OX40-L polynucleotide and polypeptide sequences. The isolation, cloning, preparation and characterization of human OX40-L is described in U.S.P.N. 6,156,878 and 6,242,566 B1, as well as U.S. Application Serial Nos: US 2001/0044523 A1 and US 2002/0077460 A1, which are incorporated herein by reference in their entirety. As mentioned above, embodiments of the present invention include anti-OX40-L antibodies as OX40 antagonists. Examples of antibodies that are directed against OX40-L are described in U.S.P.N. 6,156,878 and 6,242,566 B1, as well as U.S. Application Serial Nos: US 2001/0044523 A1 and US 2002/0077460 A1.

OX40-L is also referred to as gp34 or ACT-4-L and is expressed on the surface of select mammalian cells, such as antigen presenting cells. Human OX40-L was initially isolated and described in Miura *et al.*, *Mol Cell Biol* 11(3):1313-1325 (1991). U.S. Pat. No. 5,457, which is incorporated by reference in its entirety, describes the murine homologue of OX40-L.

OX40-L proteins of the present invention include, but are not limited to, human OX40-L polypeptides comprising amino acids 1-183 of SEQ ID NO:26 and polypeptides that comprise N-terminal, C-terminal, or internal truncations of the foregoing sequences, but retain the desired biological activity. DNA sequences encoding such human OX40

polypeptides include, but are not limited to, DNA sequences comprising the nucleotide sequence of SEQ ID NO:25.

Alternative embodiments provide soluble OX40-L polypeptides. Soluble OX40-L polypeptides comprise all or part of the extracellular domain of a native OX40 but lack the transmembrane region that would cause retention of the polypeptide on a cell membrane. The soluble OX40-L polypeptides retain the ability to bind the OX40. Soluble OX40-L polypeptides may also include part of the transmembrane region or part of the cytoplasmic domain or other sequences, provided that the soluble OX40-L protein is capable of being secreted.

In further embodiments, OX40 antagonists are polypeptide mimetics, such as, but not limited to peptidomimetics, peptibodies and/or mimotopes developed from the polypeptide sequence of OX40-L (SEQ ID NO:26) and/or OX40 (SEQ ID NO:28). Polypeptide mimetics may be developed through techniques known in the art, such as combinatorial peptide libraries. Polypeptide mimetics are peptide-containing molecules which mimic elements of protein secondary structure. A OX40-L polypeptide mimetic based on the amino acid sequence of OX40-L will bind to OX40 without activating OX40 and sterically hinder binding of endogenous OX40-L. A OX40 receptor polypeptide mimetic based on the amino acid sequence of OX40 receptor will bind to OX40-L and sterically hinder binding of endogenous OX40-L to OX40. OX40-L and OX40 peptide mimetics can be used to antagonize OX40-L binding to OX40 in a subject and thereby reduce the proinflammatory effects of OX40-L. As such, OX40 antagonists in the form of polypeptide mimetics may be used to treat inflammatory and/or immunoregulatory processes associated with cardiovascular disease.

Other forms of OX40-L and OX40 that are useful in the present invention include muteins and variants (also referred to as analogs), such as naturally occurring variants, that are substantially homologous to the native OX40-L (SEQ ID NO:26) or OX40 (SEQ ID NO:28) polypeptide sequences that retain biological activity.

This invention additionally provides for the use of OX40 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease. This invention further provides for the use of polynucleotides encoding OX40 antagonists in the manufacture of a medicament for the treatment of cardiovascular disease.

#### **F. CD39**

Alternative embodiments of the invention are directed to treating cardiovascular disease in a subject having cardiovascular disease comprising administering soluble CD39 polypeptides in combination with one or more IL-17 antagonists, IL-18 antagonists, 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists.

The molecular cloning and structural characterization of CD39 is presented in Maliszewski et al. (*J. Immunol.* 153:3574, 1994). A cDNA encoding the cell-surface molecule CD39 has been isolated, cloned and sequenced, as described in U.S. Patent Application Serial No. 09/835,147, as well as WO 00/23459, which are incorporated by reference in their entirety. The nucleic acid sequence and predicted amino acid sequence are shown in SEQ ID NO:29 and SEQ ID NO:30, respectively.

The present invention provides methods of using soluble forms of CD39 to treat cardiovascular disease, which were constructed by removing the amino- and carboxy-terminal transmembrane domains. Soluble CD39 retains the capacity of wildtype CD39 to metabolize ATP and ADP at physiologically relevant concentrations as well as the ability to block and reverse ADP-induced platelet activation and recruitment, including platelet aggregation. The use of soluble forms of CD39 is advantageous because purification of the polypeptides from recombinant host cells is facilitated, and because soluble polypeptides are generally more suitable than membrane-bound forms for clinical administration. Because CD39 inhibits platelet activation and recruitment, and therefore platelet aggregation, the present invention provides methods and compositions for inhibiting formation of a thrombus at a site in a mammal at which platelets are inappropriately activated, methods for use in controlling platelet reactivity, thereby regulating the hemostatic and thrombotic processes, and methods of inhibiting and/or reversing platelet aggregation.

CD39 contains two putative transmembrane regions, near the amino and carboxy termini, which may serve to anchor the native protein in the cell membrane. The portion of the molecule between the transmembrane regions is external to the cell. As used herein, the term "CD39 polypeptides" includes CD39, homologs of CD39, variants, fragments, and derivatives of CD39, fusion polypeptides comprising CD39, and soluble forms of CD39 polypeptides. The CD39 gene family is reported to contain at least four human members: CD39, CD39L2, CD39L3, and CD39L4 (Chadwick and Frischau, *Genomics* 50:357, 1998). CD39-L4 is reported to be a secreted apyrase (Mulero et al., *J. Biol. Chem.* 274(29):20064, 1999). Additional solCD39 variants have been constructed by fusing N-terminal sequences from CD39L2, CD39L3, or CD39L4 to a soluble portion of CD39, as described in detail in U.S. Patent Application Serial No. 09/835,147.

CD39 is an ecto-ADPase (apyrase) located on the surface of endothelial cells. This enzyme is mainly responsible for the maintenance of blood fluidity, thus maintaining platelets in the baseline (resting) state. This is accomplished by metabolism of the major platelet agonist, adenosine diphosphate, to adenosine monophosphate, which is not an agonist. Because ADP is the most important agonist of platelet aggregation, and is present in platelet releasate, a substance which catabolizes ADP is useful in treating or preventing disease states that involve inappropriate aggregation of platelets.

Apyrase activity resides in the extracellular domain of CD39. Thus, CD39 polypeptides include soluble forms of CD39 such as those having an amino terminus selected from the group consisting of amino acids 36-44 of SEQ ID NO:30, and a carboxy terminus selected from the group consisting of amino acids 471-478 of SEQ ID NO:30, and which exhibit CD39 biological activity. Soluble CD39 polypeptides also include those polypeptides which include part of either or both of the transmembrane regions, provided that the soluble CD39 polypeptide is capable of being secreted from a cell, and retains CD39 biological activity. Soluble CD39 polypeptides further include oligomers or fusion polypeptides comprising the extracellular portion of CD39, and fragments of any of these polypeptides that have biological activity.

The term "biological activity," with regards to CD39, includes apyrase enzymatic activity as well as the *ex vivo* and *in vivo* activities of CD39. Apyrases catalyze the hydrolysis of nucleoside tri- and/or di- phosphates, but a given apyrase may display different relative specificities for either nucleoside triphosphates or nucleoside diphosphates. Biological activity of soluble forms of CD39 may be determined, for example, in an ectonucleotidase or apyrase assay (e.g. ATPase or ADPase assays), or in an assay that measures inhibition of platelet aggregation. Exemplary assays are disclosed herein; those of skill in the art will appreciate that other, similar types of assays can be used to measure biological activity.

In further embodiments, CD39 compositions for the treatment of cardiovascular disease comprise polypeptide mimetics, such as, but not limited to peptidomimetics, peptibodies and/or mimotopes developed from the polypeptide sequence of CD39 (SEQ ID NO:30). Polypeptide mimetics may be developed through techniques known in the art, such as combinatorial peptide libraries. Polypeptide mimetics are peptide-containing molecules which mimic elements of protein secondary structure. A CD39 polypeptide mimetic based on the amino acid sequence of CD39 will catalyze the hydrolysis of nucleoside tri- and/or di-phosphates. As such, CD39 antagonists in the form of polypeptide mimetics may be used to treat cardiovascular disease.

Other forms of CD39 that are useful in the present invention include muteins and variants (also referred to as analogs), such as naturally occurring variants, that are substantially homologous to the native CD39 (SEQ ID NO:30) polypeptide sequences and as described in U.S. Patent Application Serial No. 09/835,147 that retain biological activity.

This invention additionally provides for the use of CD39 in the manufacture of a medicament for the treatment of cardiovascular disease. This invention further provides for the use of polynucleotides encoding CD39 in the manufacture of a medicament for the treatment of cardiovascular disease.

CD39, in all its forms as described herein and in U.S. Patent Application Serial No. 09/835,147, may be used in combination with one or more IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist in the treatment of cardiovascular disease.

**G. FURTHER EMBODIMENTS OF IL-17, IL-18, 4-1BB, CD30 AND OX40 ANTAGONISTS AND CD39**

Other forms of the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 that are useful in the present invention include muteins and variants (also referred to as analogs), such as naturally occurring variants, that are substantially homologous to the native sequences provided herein, as well as the sequences provided in the patents incorporated by reference.

Substantially homologous means a variant amino acid sequence that is at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 96%, at least 97%, at least 98% or at least 99% identical to the native amino acid sequences, as disclosed above. The percent identity of two amino acid or two nucleic acid sequences can be determined by visual inspection and mathematical calculation, or more preferably, the comparison is done by comparing sequence information using a computer program. An exemplary, preferred computer program is the Genetics Computer Group (GCG; Madison, WI) Wisconsin package version 10.0 program, 'GAP' (Devereux et al., 1984, *Nucl. Acids Res.* 12: 387). The preferred default parameters for the 'GAP' program includes: (1) The GCG implementation of a unary comparison matrix (containing a value of 1 for identities and 0 for non-identities) for nucleotides, and the weighted amino acid comparison matrix of Gribskov and Burgess, *Nucl. Acids Res.* 14:6745, 1986, as described by Schwartz and Dayhoff, eds., *Atlas of Polypeptide Sequence and Structure*, National Biomedical Research Foundation, pp. 353-358, 1979; or other comparable comparison matrices; (2) a penalty of 30 for each gap and an additional penalty of 1 for each symbol in each gap for amino acid sequences, or penalty of 50 for each gap and an additional penalty of 3 for each symbol in each gap for nucleotide sequences; (3) no penalty for end gaps; and (4) no maximum penalty for long gaps. Other programs used by those skilled in the art of sequence comparison can also be used, such as, for example, the BLASTN program version 2.0.9, available for use via the National Library of Medicine website [www.ncbi.nlm.nih.gov/gorf/wblast2.cgi](http://www.ncbi.nlm.nih.gov/gorf/wblast2.cgi), or the UW-BLAST 2.0 algorithm. Standard default parameter settings for UW-BLAST 2.0 are described at the following Internet site: [sapiens.wustl.edu/blast/blast/#Features](http://sapiens.wustl.edu/blast/blast/#Features). In addition, the BLAST algorithm uses the BLOSUM62 amino acid scoring matrix, and optional parameters that can be used are as follows: (A) inclusion of a filter to mask segments of the query sequence that have low compositional complexity (as determined by the SEG program of Wootton and Federhen (Computers and Chemistry, 1993); also see Wootton and Federhen, 1996, *Analysis of compositionally biased regions in sequence databases*, *Methods Enzymol.* 266: 554-71) or segments consisting of short-periodicity internal repeats (as determined by the XNU program

of Claverie and States (Computers and Chemistry, 1993)), and (B) a statistical significance threshold for reporting matches against database sequences, or E-score (the expected probability of matches being found merely by chance, according to the stochastic model of Karlin and Altschul (1990); if the statistical significance ascribed to a match is greater than this E-score threshold, the match will not be reported.); preferred E-score threshold values are 0.5, or in order of increasing preference, 0.25, 0.1, 0.05, 0.01, 0.001, 0.0001, 1e-5, 1e-10, 1e-15, 1e-20, 1e-25, 1e-30, 1e-40, 1e-50, 1e-75, or 1e-100.

Such variants include polypeptides that are substantially homologous to native IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 sequences, but which have an amino acid sequence different from that of a native IL-17 receptor because of one or more deletions, insertions or substitutions. Particular embodiments include, but are not limited to, IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides that comprise at least one conservative amino acid substitution. Alternative embodiments comprise IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides comprising from one to ten deletions, insertions or substitutions of amino acid residues, when compared to a native sequences. The IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 -encoding polynucleotides of the present invention include variants that differ from a native IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polynucleotide sequence because of one or more deletions, insertions or substitutions, but that encode a biologically active polypeptide. Included as variants of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides are those variants that are naturally occurring, such as allelic forms and alternatively spliced forms, as well as variants that have been constructed by modifying the amino acid sequence of an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptide or the nucleotide sequence of a nucleic acid encoding an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptide.

As mentioned above, IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 variants may comprise a sequence having at least one conservatively substituted amino acid, meaning that a given amino acid residue is replaced by a residue having similar physiochemical characteristics. Alternative embodiments comprise IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 variants that comprise between 1-10, 1-20 or 1-30 conservatively substituted sequences. Generally, substitutions for one or more amino acids present in the native polypeptide should be made conservatively. Examples of conservative substitutions include substitution of amino acids outside of the active domain(s), and

substitution of amino acids that do not alter the secondary and/or tertiary structure of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39. Examples of conservative substitutions include substitution of one aliphatic residue for another, such as Ile, Val, Leu, or Ala for one another, or substitutions of one polar residue for another, such as between Lys and Arg; Glu and Asp; or Gln and Asn. Other such conservative substitutions, for example, substitutions of entire regions having similar hydrophobicity characteristics, are well known. Naturally occurring variants are also encompassed by the invention. Examples of such variants are proteins that result from alternate mRNA splicing events or from proteolytic cleavage of the native protein, wherein the native biological property is retained.

For example, a "conservative amino acid substitution" may involve a substitution of a native amino acid residue with a nonnative residue such that there is little or no effect on the polarity or charge of the amino acid residue at that position. Furthermore, any native residue in the polypeptide may also be substituted with alanine, as has been previously described for "alanine scanning mutagenesis" (see, for example, MacLennan *et al.*, 1998, *Acta Physiol. Scand. Suppl.* 643:55-67; Sasaki *et al.*, 1998, *Adv. Biophys.* 35:1-24, which discuss alanine scanning mutagenesis).

Desired amino acid substitutions (whether conservative or non-conservative) can be determined by those skilled in the art at the time such substitutions are desired. For example, amino acid substitutions can be used to identify important residues of the peptide sequence, or to increase or decrease the affinity of the peptide or vehicle-peptide molecules (see preceding formulae) described herein. Exemplary amino acid substitutions are set forth in Table 1.

Table 1—Amino Acid Substitutions

Original Residues	Exemplary Substitutions	Preferred Substitutions
Ala (A)	Val, Leu, Ile	Val
Arg (R)	Lys, Gln, Asn	Lys
Asn (N)	Gln	Gln
Asp (D)	Glu	Glu
Cys (C)	Ser, Ala	Ser
Gln (Q)	Asn	Asn
Glu (E)	Asp	Asp
Gly (G)	Pro, Ala	Ala
His (H)	Asn, Gln, Lys, Arg	Arg



Ile (I)	Leu, Val, Met, Ala, Phe, Norleucine	Leu
Leu (L)	Norleucine, Ile, Val, Met, Ala, Phe	Ile
Lys (K)	Arg, 1,4 Diamino-butyrlic Acid, Gln, Asn	Arg
Met (M)	Leu, Phe, Ile	Leu
Phe (F)	Leu, Val, Ile, Ala, Tyr	Leu
Pro (P)	Ala	Gly
Ser (S)	Thr, Ala, Cys	Thr
Thr (T)	Ser	Ser
Trp (W)	Tyr, Phe	Tyr
Tyr (Y)	Trp, Phe, Thr, Ser	Phe
Val (V)	Ile, Met, Leu, Phe, Ala, Norleucine	Leu

In certain embodiments, conservative amino acid substitutions also encompass non-naturally occurring amino acid residues which are typically incorporated by chemical peptide synthesis rather than by synthesis in biological systems.

As noted above, naturally occurring residues may be divided into classes based on common sidechain properties that may be useful for modifications of sequence. For example, non-conservative substitutions may involve the exchange of a member of one of these classes for a member from another class. Such substituted residues may be introduced into regions of the peptide that are homologous with non-human orthologs, or into the non-homologous regions of the molecule. In addition, one may also make modifications using P or G for the purpose of influencing chain orientation.

In making such modifications, the hydropathic index of amino acids may be considered. Each amino acid has been assigned a hydropathic index on the basis of their hydrophobicity and charge characteristics, these are: isoleucine (+4.5); valine (+4.2); leucine (+3.8); phenylalanine (+2.8); cysteine/cystine (+2.5); methionine (+1.9); alanine (+1.8); glycine (-0.4); threonine (-0.7); serine (-0.8); tryptophan (-0.9); tyrosine (-1.3); proline (-1.6); histidine (-3.2); glutamate (-3.5); glutamine (-3.5); aspartate (-3.5); asparagine (-3.5); lysine (-3.9); and arginine (-4.5).

The importance of the hydropathic amino acid index in conferring interactive biological function on a protein is understood in the art. (Kyte, *et al.*, *J. Mol. Biol.*, 157: 105-131 (1982)). It is known that certain amino acids may be substituted for other amino acids having a similar hydropathic index or score and still retain a similar biological activity. In

making changes based upon the hydrophathic index, the substitution of amino acids whose hydrophathic indices are within  $\pm 2$  is preferred, those which are within  $\pm 1$  are particularly preferred, and those within  $\pm 0.5$  are even more particularly preferred.

It is also understood in the art that the substitution of like amino acids can be made effectively on the basis of hydrophilicity. The greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of its adjacent amino acids, correlates with its immunogenicity and antigenicity, i.e., with a biological property of the protein.

The following hydrophilicity values have been assigned to amino acid residues: arginine (+3.0); lysine (+3.0); aspartate (+3.0  $\pm$  1); glutamate (+3.0  $\pm$  1); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); threonine (-0.4); proline (-0.5  $\pm$  1); alanine (-0.5); histidine (-0.5); cysteine (-1.0); methionine (-1.3); valine (-1.5); leucine (-1.8); isoleucine (-1.8); tyrosine (-2.3); phenylalanine (-2.5); tryptophan (-3.4). In making changes based upon similar hydrophilicity values, the substitution of amino acids whose hydrophilicity values are within  $\pm 2$  is preferred, those which are within  $\pm 1$  are particularly preferred, and those within  $\pm 0.5$  are even more particularly preferred. One may also identify epitopes from primary amino acid sequences on the basis of hydrophilicity. These regions are also referred to as "epitopic core regions."

A skilled artisan will be able to determine suitable variants of the polypeptide as set forth in the foregoing sequences using well known techniques. For identifying suitable areas of the molecule that may be changed without destroying activity, one skilled in the art may target areas not believed to be important for activity. For example, when similar polypeptides with similar activities from the same species or from other species are known, one skilled in the art may compare the amino acid sequence of a peptide to similar peptides. With such a comparison, one can identify residues and portions of the molecules that are conserved among similar polypeptides. It will be appreciated that changes in areas of a peptide that are not conserved relative to such similar peptides would be less likely to adversely affect the biological activity and/or structure of the peptide. One skilled in the art would also know that, even in relatively conserved regions, one may substitute chemically similar amino acids for the naturally occurring residues while retaining activity (conservative amino acid residue substitutions). Therefore, even areas that may be important for biological activity or for structure may be subject to conservative amino acid substitutions without destroying the biological activity or without adversely affecting the peptide structure.

Additionally, one skilled in the art can review structure-function studies identifying residues in similar peptides that are important for activity or structure. In view of such a comparison, one can predict the importance of amino acid residues in a peptide that correspond to amino acid residues that are important for activity or structure in similar peptides. One skilled in the art may opt for chemically similar amino acid substitutions for such predicted important amino acid residues of the peptides.

One skilled in the art can also analyze the three-dimensional structure and amino acid sequence in relation to that structure in similar polypeptides. In view of that information, one skilled in the art may predict the alignment of amino acid residues of a peptide with respect to its three dimensional structure. One skilled in the art may choose not to make radical changes to amino acid residues predicted to be on the surface of the protein, since such residues may be involved in important interactions with other molecules. Moreover, one skilled in the art may generate test variants containing a single amino acid substitution at each desired amino acid residue. The variants can then be screened using activity assays known to those skilled in the art. Such data could be used to gather information about suitable variants. For example, if one discovered that a change to a particular amino acid residue resulted in destroyed, undesirably reduced, or unsuitable activity, variants with such a change would be avoided. In other words, based on information gathered from such routine experiments, one skilled in the art can readily determine the amino acids where further substitutions should be avoided either alone or in combination with other mutations.

A number of scientific publications have been devoted to the prediction of secondary structure. See, Moult J., *Curr. Op. in Biotech.*, 7(4): 422-427 (1996), Chou *et al.*, *Biochemistry*, 13(2): 222-245 (1974); Chou *et al.*, *Biochemistry*, 113(2): 211-222 (1974); Chou *et al.*, *Adv. Enzymol. Relat. Areas Mol. Biol.*, 47: 45-148 (1978); Chou *et al.*, *Ann. Rev. Biochem.*, 47: 251-276 and Chou *et al.*, *Biophys. J.*, 26: 367-384 (1979). Moreover, computer programs are currently available to assist with predicting secondary structure. One method of predicting secondary structure is based upon homology modeling. For example, two polypeptides or proteins which have a sequence identity of greater than 30%, or similarity greater than 40% often have similar structural topologies. The recent growth of the protein structural data base (PDB) has provided enhanced predictability of secondary structure, including the potential number of folds within a polypeptide's or protein's structure. See Holm, *et al.*, *Nucl. Acid. Res.*, 27(1): 244-247 (1999). It has been suggested (Brenner *et al.*, *Curr. Op. Struct. Biol.*, 7(3): 369-376 (1997)) that there are a limited number of folds in a given polypeptide or protein and that once a critical number of structures have been resolved, structural prediction will gain dramatically in accuracy.

Additional methods of predicting secondary structure include "threading" (Jones, D., *Curr. Opin. Struct. Biol.*, 7(3): 377-87 (1997); Sippl, *et al.*, *Structure*, 4(1): 15-9 (1996)), "profile analysis" (Bowie, *et al.*, *Science*, 253: 164-170 (1991); Gribskov, *et al.*, *Meth. Enzym.*, 183: 146-159 (1990); Gribskov, *et al.*, *Proc. Nat. Acad. Sci.*, 84(13): 4355-8 (1987)), and "evolutionary linkage" (See Holm, *supra*, and Brenner, *supra*).

Embodiments of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 variants include IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 variants include polypeptide sequences that are at least about 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99%

identical in amino acid sequence to the respective amino acid sequence for IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39, as described above.

Further modifications in the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptide or IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polynucleotide sequences can be made by those skilled in the art using known techniques. Modifications of interest in the polypeptide sequences can include the alteration, substitution, replacement, insertion or deletion of a selected amino acid. For example, one or more of the cysteine residues can be deleted or replaced with another amino acid to alter the conformation of the molecule, an alteration which may involve preventing formation of incorrect intramolecular disulfide bridges upon folding or renaturation. Techniques for such alteration, substitution, replacement, insertion or deletion are well known to those skilled in the art (see, e.g., U.S. Pat. No. 4,518,584). As another example, N-glycosylation sites in the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 extracellular domain can be modified to preclude glycosylation, allowing expression of a reduced carbohydrate analog in mammalian and yeast expression systems. N-glycosylation sites in eukaryotic polypeptides are characterized by an amino acid triplet Asn-X-Y, wherein X is any amino acid except Pro and Y is Ser or Thr. Appropriate substitutions, additions, or deletions to the nucleotide sequence encoding these triplets will result in prevention of attachment of carbohydrate residues at the Asn side chain. Alteration of a single nucleotide, chosen so that Asn is replaced by a different amino acid, for example, is sufficient to inactivate an N-glycosylation site. Alternatively, the Ser or Thr can be replaced with another amino acid, such as Ala. Procedures for inactivating N-glycosylation sites in polypeptides are known in the art and include, for example, those described in U.S. Patent 5,071,972. Additional variants within the scope of the invention include IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides that can be modified to create derivatives thereof by forming covalent or aggregative conjugates with other chemical moieties, such as glycosyl groups, lipids, phosphate, acetyl groups and the like. Covalent derivatives can be prepared by linking the chemical moieties to functional groups on amino acid side chains or at the N-terminus or C-terminus of a polypeptide. Preferably, such alteration, substitution, replacement, insertion or deletion does not diminish the biological activity of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39. One example is a variant that binds with essentially the same binding affinity as does the native form. Binding affinity can be measured by conventional procedures, e.g., as described in U.S. Patent No. 5,512,457 and as set forth herein. Furthermore, IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 molecules may be modified by the addition of one or

more water-soluble polymers, such as, but not limited to, polyethylene glycol to increase bio-availability and/or pharmacokinetic half-life.

Various means for attaching chemical moieties useful for increase bio-availability and/or pharmacokinetic half-life are currently available, see, e.g., Patent Cooperation Treaty (“PCT”) International Publication No. WO 96/11953, entitled “N-Terminally Chemically Modified Protein Compositions and Methods,” herein incorporated by reference in its entirety. This PCT publication discloses, among other things, the selective attachment of water soluble polymers to the N-terminus of proteins.

A preferred polymer vehicle is polyethylene glycol (PEG). The PEG group may be of any convenient molecular weight and may be linear or branched. The average molecular weight of the PEG will preferably range from about 2 kiloDalton (“kD”) to about 100 kD, more preferably from about 5 kD to about 50 kD, most preferably from about 5 kD to about 10 kD. The PEG groups will generally be attached to the compounds of the invention via acylation or reductive alkylation through a reactive group on the PEG moiety (e.g., an aldehyde, amino, thiol, or ester group) to a reactive group on the inventive compound (e.g., an aldehyde, amino, or ester group).

A useful strategy for the PEGylation of synthetic peptides consists of combining, through forming a conjugate linkage in solution, a peptide and a PEG moiety, each bearing a special functionality that is mutually reactive toward the other. The peptides can be easily prepared with conventional solid phase synthesis. The peptides are “preactivated” with an appropriate functional group at a specific site. The precursors are purified and fully characterized prior to reacting with the PEG moiety. Ligation of the peptide with PEG usually takes place in aqueous phase and can be easily monitored by reverse phase analytical HPLC. The PEGylated peptides can be easily purified by preparative HPLC and characterized by analytical HPLC, amino acid analysis and laser desorption mass spectrometry.

Polysaccharide polymers are another type of water-soluble polymer which may be used for protein modification. Dextrans are polysaccharide polymers comprised of individual subunits of glucose predominantly linked by  $\alpha$ 1-6 linkages. The dextran itself is available in many molecular weight ranges, and is readily available in molecular weights from about 1 kD to about 70 kD. Dextran is a suitable water soluble polymer for use in the present invention as a vehicle by itself or in combination with another vehicle (e.g., Fc). See, for example, WO 96/11953 and WO 96/05309. The use of dextran conjugated to therapeutic or diagnostic immunoglobulins has been reported; see, for example, European Patent Publication No. 0 315 456, which is hereby incorporated by reference in its entirety. Dextran of about 1 kD to about 20 kD is preferred when dextran is used as a vehicle in accordance with the present invention.

Additional IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 derivatives include covalent or aggregative conjugates of the

polypeptides with other polypeptides or polypeptides, such as by synthesis in recombinant culture as N-terminal or C-terminal fusions. Examples of fusion polypeptides are discussed below in connection with oligomers. Further, fusion polypeptides can comprise peptides added to facilitate purification and identification. Such peptides include, for example, poly-His or the antigenic identification peptides described in U.S. Patent No. 5,011,912 and in Hopp et al., Bio/Technology 6:1204, 1988. One such peptide is the FLAG<sup>®</sup> octapeptide (SEQ ID NO:31), which is highly antigenic and provides an epitope reversibly bound by a specific monoclonal antibody, enabling rapid assay and facile purification of expressed recombinant polypeptide. A murine hybridoma designated 4E11 produces a monoclonal antibody that binds the FLAG<sup>®</sup> peptide in the presence of certain divalent metal cations, as described in U.S. Patent 5,011,912. The 4E11 hybridoma cell line has been deposited with the American Type Culture Collection under accession no. HB 9259. Monoclonal antibodies that bind the FLAG<sup>®</sup> peptide are available from Eastman Kodak Co., Scientific Imaging Systems Division, New Haven, Connecticut.

Additional embodiments of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 that may be used in the methods described herein include oligomers or fusion polypeptides that contain IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide, one or more fragments of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39, or any of the derivative or variant forms of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 as disclosed herein, as well as in the U.S. patents listed above. In particular embodiments, the oligomers comprise soluble IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptides. Oligomers can be in the form of covalently linked or non-covalently-linked multimers, including dimers, trimers, or higher oligomers. In alternative embodiments, IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 oligomers comprise multiple IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides joined via covalent or non-covalent interactions between peptide moieties fused to the polypeptides, such peptides having the property of promoting oligomerization. Leucine zippers and certain polypeptides derived from antibodies are among the peptides that can promote oligomerization of the polypeptides attached thereto, as described in more detail below.

Immunoglobulin-based Oligomers. Suitable forms of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 antagonists include chimeric proteins which include a second polypeptide that may promote the spontaneous formation by the chimeric protein of a dimer, trimer or higher order multimer that is capable of binding their respective cognates and thereby inhibiting or reducing the effects of

inflammation and symptoms of cardiovascular disease. Chimeric proteins used as antagonists may be proteins that contain portions of an antibody molecule and a soluble polypeptide from IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39. Suitable fusion proteins include an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptide, e.g. the extracellular domain, or a fragment of the extracellular domain, linked to an immunoglobulin Fc region. Fragments of a Fc region may also be used, as well as Fc muteins that exhibit decreased affinity for Fc receptors. Soluble IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39, as well as fragments thereof, can be fused directly or through linker sequences to the Fc portion of an immunoglobulin.

One embodiment of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 antagonist is directed to a dimer comprising two fusion polypeptides created by fusing an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide to a Fc polypeptide derived from an antibody. A gene fusion encoding such a fusion polypeptide is inserted into an appropriate expression vector. IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39-Fc fusion polypeptides are expressed in host cells transformed with the recombinant expression vector, and allowed to assemble much like antibody molecules, whereupon interchain disulfide bonds form between the Fc moieties to yield divalent molecules. One suitable Fc polypeptide, described in PCT application WO 93/10151, is a single chain polypeptide extending from the N-terminal hinge region to the native C-terminus of the Fc region of a human IgG1 antibody. For a bivalent form of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39, such a fusion could be to the Fc portion of an IgG molecule. Other immunoglobulin isotypes can also be used to generate such fusions. For example, a polypeptide-IgM fusion would generate a decavalent form of the polypeptide of the invention.

The term "Fc polypeptide" as used herein includes native and mutein forms of polypeptides made up of the Fc region of an antibody comprising any or all of the CH domains of the Fc region. Truncated forms of such polypeptides containing the hinge region that promotes dimerization are also included. Preferred Fc polypeptides comprise an Fc polypeptide derived from a human IgG1 antibody. As one alternative, an oligomer is prepared using polypeptides derived from immunoglobulins. Preparation of fusion polypeptides comprising certain heterologous polypeptides fused to various portions of antibody-derived polypeptides (including the Fc domain) are known in the art and have been described, e.g., by Ashkenazi et al. (*PNAS USA* 88:10535, 1991); Byrn et al. (*Nature* 344:677, 1990); and Hollenbaugh and Aruffo ("Construction of Immunoglobulin Fusion Polypeptides", in *Current Protocols in Immunology*, Suppl. 4, pages 10.19.1 - 10.19.11, 1992). Another useful Fc polypeptide is the Fc mutein described in U.S. Patent 5,457,035

and in Baum et al., (*EMBO J.* 13:3992-4001, 1994). The amino acid sequence of this mutein is identical to that of the native Fc sequence presented in WO 93/10151, except that amino acid 19 has been changed from Leu to Ala, amino acid 20 has been changed from Leu to Glu, and amino acid 22 has been changed from Gly to Ala. The mutein exhibits reduced affinity for Fc receptors. The above-described fusion polypeptides comprising Fc moieties (and oligomers formed therefrom) offer the advantage of facile purification by affinity chromatography over Polypeptide A or Polypeptide G columns. In other embodiments, the polypeptides of the invention can be substituted for the variable portion of an antibody heavy or light chain. If fusion polypeptides are made with both heavy and light chains of an antibody, it is possible to form an oligomer with as many as four IL-17R extracellular regions.

Peptide-linker Based Oligomers. Alternatively, the oligomer is a fusion polypeptide comprising multiple IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptides, with or without peptide linkers (spacer peptides). Among the suitable peptide linkers are those described in U.S. Patents 4,751,180 and 4,935,233. A DNA sequence encoding a desired peptide linker can be inserted between, and in the same reading frame as, the DNA sequences of the invention, using any suitable conventional technique. For example, a chemically synthesized oligonucleotide encoding the linker can be ligated between the sequences. In particular embodiments, a fusion polypeptide comprises from two to four soluble IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptides, separated by peptide linkers. Suitable peptide linkers, their combination with other polypeptides, and their use are well known by those skilled in the art.

Oligomeric forms of IL-17, IL-18, 4-1BB, CD30, OX40 and CD39 antagonists suitable for use in treating cardiovascular disease also include an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide, the extracellular domain of an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide, or an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 antagonistic fragment of the extracellular domain associated with a zipper domain, such as zipper proteins described in U.S. Patent 5,716,805, the disclosure of which is incorporated by reference herein. Other Examples of zipper domains are those found in the yeast transcription factor GCN4 and a heat-stable DNA-binding protein found in rat liver (C/EBP; Landschulz et al., *Science* 243:1681, 1989), the nuclear transforming proteins, *fos* and *jun*, which preferentially form a heterodimer (O'Shea et al., *Science* 245:646, 1989; Turner and Tjian, *Science* 243:1689, 1989), and the gene product of the murine proto-oncogene, *c-myc* (Landschulz et al., *Science* 240:1759, 1988). The fusogenic proteins of several different viruses, including paramyxovirus, coronavirus, measles virus and many retroviruses, also possess leucine zipper



domains (Buckland and Wild, *Nature* 338:547, 1989; Britton, *Nature* 353:394, 1991; Delwart and Mosialos, *AIDS Research and Human Retroviruses* 6:703, 1990). Leucine zipper domains are peptides that promote oligomerization of the polypeptides in which they are found. Leucine zippers were originally identified in several DNA-binding polypeptides and have since been found in a variety of different polypeptides. Among the known leucine zippers are naturally occurring peptides and derivatives thereof that dimerize or trimerize. The zipper domain (also referred to herein as an oligomerizing, or oligomer-forming, domain) comprises a repetitive heptad repeat, often with four or five leucine residues interspersed with other amino acids. Use of leucine zippers and preparation of oligomers using leucine zippers are well known in the art.

The present invention comprises fusion polypeptides with or without spacer amino acid linking groups. For example, two soluble IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 domains can be linked with a linker sequence, such as (Gly)<sub>4</sub>Ser(Gly)<sub>5</sub>Ser (SEQ ID NO:32), which is described in United States Patent 5,073,627. Other linker sequences include, for example, GlyAlaGlyGlyAlaGlySer(Gly)<sub>5</sub>Ser (SEQ ID NO:33), (Gly<sub>4</sub>Ser)<sub>2</sub> (SEQ ID NO:34), (GlyThrPro)<sub>3</sub> (SEQ ID NO:35), and (Gly<sub>4</sub>Ser)<sub>3</sub>Gly<sub>4</sub>SerGly<sub>5</sub>Ser (SEQ ID NO:36).

Nucleic acid sequences encoding soluble IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides having altered glycosylation sites, deleted or substituted Cys residues, or modified proteolytic cleavage sites, nucleic acid sequences encoding sub-units of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides or fusion polypeptides of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 with other peptides, allelic variants of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39, mammalian homologs of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39, and nucleic acid sequences encoding IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 polypeptides derived from alternative mRNA constructs, or those that encode peptide having substituted or additional amino acids, are examples of nucleic acid sequences according to the invention.

Due to degeneracy of the genetic code, there can be considerable variation in nucleotide sequences encoding the same amino acid sequence. Embodiments include sequences capable of hybridizing under moderately stringent conditions. The basic parameters affecting the choice of hybridization conditions and guidance for devising suitable conditions are set forth by Sambrook, Fritsch, and Maniatis (1989, *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., chapters 9 and 11; and *Current Protocols in Molecular Biology*, 1995, Ausubel et al., eds., John Wiley & Sons, Inc., sections 2.10 and 6.3-6.4), and can be readily determined by those

having ordinary skill in the art based on, for example, the length and/or base composition of the DNA. One way of achieving moderately stringent conditions involves the use of a prewashing solution containing 5 x SSC, 0.5% SDS, 1.0 mM EDTA (pH 8.0), hybridization buffer of about 50% formamide, 6 x SSC, and a hybridization temperature of about 55 degrees C (or other similar hybridization solutions, such as one containing about 50% formamide, with a hybridization temperature of about 42 degrees C), and washing conditions of about 60 degrees C, in 0.5 x SSC, 0.1% SDS. Generally, highly stringent conditions are defined as hybridization conditions as above, but with washing at approximately 68 degrees C, 0.2 x SSC, 0.1% SDS. SSPE (1xSSPE is 0.15M NaCl, 10 mM NaH<sub>2</sub>PO<sub>4</sub>, and 1.25 mM EDTA, pH 7.4) can be substituted for SSC (1xSSC is 0.15M NaCl and 15 mM sodium citrate) in the hybridization and wash buffers; washes are performed for 15 minutes after hybridization is complete. It should be understood that the wash temperature and wash salt concentration can be adjusted as necessary to achieve a desired degree of stringency by applying the basic principles that govern hybridization reactions and duplex stability, as known to those skilled in the art and described further below (see, e.g., Sambrook et al., 1989). When hybridizing a nucleic acid to a target nucleic acid of unknown sequence, the hybrid length is assumed to be that of the hybridizing nucleic acid. When nucleic acids of known sequence are hybridized, the hybrid length can be determined by aligning the sequences of the nucleic acids and identifying the region or regions of optimal sequence complementarity. The hybridization temperature for hybrids anticipated to be less than 50 base pairs in length should be 5 to 10 degrees C less than the melting temperature (T<sub>m</sub>) of the hybrid, where T<sub>m</sub> is determined according to the following equations. For hybrids less than 18 base pairs in length, T<sub>m</sub> (degrees C) = 2(# of A + T bases) + 4(# of G + C bases). For hybrids above 18 base pairs in length, T<sub>m</sub> (degrees C) = 81.5 + 16.6(log<sub>10</sub> [Na<sup>+</sup>]) + 0.41(% G + C) - (600/N), where N is the number of bases in the hybrid, and [Na<sup>+</sup>] is the concentration of sodium ions in the hybridization buffer ([Na<sup>+</sup>] for 1xSSC = 0.165M). Preferably, each such hybridizing nucleic acid has a length that is at least 15 nucleotides (or more preferably at least 18 nucleotides, or at least 20 nucleotides, or at least 25 nucleotides, or at least 30 nucleotides, or at least 40 nucleotides, or most preferably at least 50 nucleotides), or at least 25% (more preferably at least 50%, or at least 60%, or at least 70%, and most preferably at least 80%) of the length of the nucleic acid of the present invention to which it hybridizes, and has at least 60% sequence identity (more preferably at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 97.5%, or at least 99%, and most preferably at least 99.5%) with the nucleic acid of the present invention to which it hybridizes, where sequence identity is determined by comparing the sequences of the hybridizing nucleic acids when aligned so as to maximize overlap and identity while minimizing sequence gaps as described in more detail above.

In alternative embodiments, IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polynucleotides include those that encode polypeptides that are at least 75%, or at least 80%, or at least 85%, or at least 90%, or at least 95%, or at least 96%, or at least 97%, or at least 98%, or at least 99% identical in amino acid sequence to the amino acid sequence of native or at least 80% polypeptide sequences as set forth above and in the sequence listing. For polynucleotides that encode a fragment of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39, percent identity of the fragment is based on percent identity to the corresponding portion of full-length IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide, respectively.

Mutations can be introduced into nucleic acids by synthesizing oligonucleotides containing a mutant sequence, flanked by restriction sites enabling ligation to fragments of the native sequence. Following ligation, the resulting reconstructed sequence encodes a variant having the desired amino acid insertion, substitution, or deletion.

Alternatively, oligonucleotide-directed site-specific mutagenesis procedures can be employed to provide an altered gene having particular codons altered according to the substitution, deletion, or insertion required. Exemplary methods of making the alterations set forth above are disclosed by Walder et al. (*Gene* 42:133, 1986); Bauer et al. (*Gene* 37:73, 1985); Craik (*BioTechniques*, January 1985, 12-19); Smith et al. (*Genetic Engineering: Principles and Methods*, Plenum Press, 1981); and U.S. Patent Nos. 4,518,584 and 4,737,462 disclose suitable techniques, and are incorporated by reference herein.

Polynucleotide sequences that encode IL-17 receptor polypeptides comprising various additions or substitutions of amino acid residues or sequences, or deletions of terminal or internal residues or sequences not needed for biological activity can be prepared. For example, N-glycosylation sites can be modified to preclude glycosylation while allowing expression of a homogeneous, reduced carbohydrate variant using yeast expression systems. N-glycosylation sites in eukaryotic polypeptides are characterized by an amino acid triplet Asn-X-Y, wherein X is any amino acid except Pro and Y is Ser or Thr. Appropriate modifications to the nucleotide sequence encoding this triplet will result in substitutions, additions or deletions that prevent attachment of carbohydrate residues at the Asn side chain.

In another example, sequences encoding Cys residues can be altered to cause the Cys residues to be deleted or replaced with other amino acids, preventing formation of incorrect intramolecular disulfide bridges upon renaturation. Thus, Cys residues may be replaced with another amino acid or deleted without affecting polypeptide tertiary structure or disulfide bond formation.

Other approaches to mutagenesis involve modification of sequences encoding dibasic amino acid residues to enhance expression in yeast systems in which KEX2 protease activity is present. Other variants are prepared by modification of adjacent dibasic amino acid

residues, to enhance expression in yeast systems in which KEX2 protease activity is present. EP 212,914 discloses the use of site-specific mutagenesis to inactivate KEX2 protease processing sites in a polypeptide. KEX2 protease processing sites are inactivated by deleting, adding or substituting residues to alter Arg-Arg, Arg-Lys, and Lys-Arg pairs to eliminate the occurrence of these adjacent basic residues. Similar modification may be made to sequences encoding sites recognized and cleaved by other proteolytic enzymes. Sub-units of a IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide may be constructed by deleting sequences encoding terminal or internal residues or sequences not necessary for biological activity. Sequences encoding fusion polypeptides as described below may be constructed by ligating sequences encoding additional amino acid residues to the inventive sequences without affecting biological activity.

Mutations in nucleotide sequences constructed for expression of a soluble IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 must, of course, preserve the reading frame phase of the coding sequences and preferably will not create complementary regions that could hybridize to produce secondary mRNA structures such as loops or hairpins which would adversely affect translation of the receptor mRNA. Although a mutation site may be predetermined, it is not necessary that the nature of the mutation *per se* be predetermined. For example, in order to select for optimum characteristics of mutants at a given site, random mutagenesis may be conducted at the target codon and the expressed mutated polypeptides screened for the desired activity.

Not all mutations in the nucleotide sequence which encodes a IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptide will be expressed in the final product, for example, nucleotide substitutions may be made to enhance expression, primarily to avoid secondary structure loops in the transcribed mRNA or to provide codons that are more readily translated by the selected host, e.g., the well-known *E. coli* preference codons for *E. coli* expression.

In the genome, IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and/or CD39 polypeptides are encoded by multi-exon genes. The present invention further includes alternative mRNA constructs that can be attributed to different mRNA splicing events following transcription and which hybridize with the cDNAs disclosed herein under conditions of moderate stringency, as defined above.

#### **H. ANTIBODIES AS IL-17, IL-18, 4-1BB, CD30 and OX40 ANTAGONISTS.**

IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists include antibodies that specifically bind IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40 or OX40-L. More specifically, IL-17 antagonists include antibodies directed against IL-17 that specifically bind IL-17 and partially or completely inhibit binding of IL-17 to IL-17 receptor,

and antibodies directed against IL-17 receptor that specifically bind IL-17 receptor and inhibit binding of IL-17 without themselves activating the IL-17 receptor; IL-18 antagonists include antibodies directed against IL-18 that specifically bind IL-18 and partially or completely inhibit binding of IL-18 to IL-18R; antibodies directed against IL-18R that specifically bind IL-18R and inhibit receptor binding of IL-18 without themselves transducing a signal via IL-18R; 4-1BB antagonists include antibodies directed against 4-1BB that specifically bind 4-1BB and partially or completely inhibit binding of 4-1BB to 4-1BB-L; antibodies directed against 4-1BB that specifically bind 4-1BB and inhibit binding of 4-1BB-L without themselves transducing a signal via 4-1BB; CD30 antagonists include antibodies directed against CD30-L that specifically bind CD30-L and partially or completely inhibit binding of CD30-L to CD30; antibodies directed against CD30 that specifically bind CD30 and inhibit binding of CD30-L without themselves activating the CD30; and, OX40 antagonists include antibodies directed against OX40-L that specifically bind OX40-L and partially or completely inhibit binding of OX40-L to OX40; antibodies directed against OX40 that specifically bind OX40 and inhibit binding of OX40-L without themselves activating the OX40.

IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40 or OX40-L, as well as fragments, variants, muteins, derivatives and fusion proteins thereof, as set forth above, can be employed as “immunogens” in producing antibodies that may be used in the diagnosis and treatment of cardiovascular disease. In making IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists in the form of antibodies, when reference is made to IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40 or OX40-L it is understood to also encompass fragments, variants, muteins, derivatives and fusion proteins thereof. A number of antibodies have been made to IL-17, IL-17R, IL-18, IL-18R, 4-1BB, 4-1BB-L, OX40, CD30, CD30-L and CD39, as shown in Table 3 of Example 6.

IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 contain antigenic determinants or epitopes that elicit the formation of antibodies. These antigenic determinants or epitopes can be either linear or conformational (discontinuous). Linear epitopes are composed of a single section of amino acids of the polypeptide, while conformational or discontinuous epitopes are composed of amino acids sections from different regions of the polypeptide chain that are brought into close proximity upon polypeptide folding. Epitopes can be identified by any of the methods known in the art. Additionally, epitopes from the polypeptides of the invention can be used as research reagents, in assays, and to purify specific binding antibodies from substances such as polyclonal sera or supernatants from cultured hybridomas. Such epitopes or variants thereof can be produced using techniques known in the art such as solid-phase synthesis, chemical or enzymatic cleavage of a polypeptide, or using recombinant DNA technology.

Antibodies to IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 can conveniently be generated against a recombinantly produced form of the proteins described above and provided in the respective sequence identifier numbers. IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists that are antibodies include but are not limited to polyclonal antibodies, monoclonal antibodies (mAbs), humanized or chimeric antibodies, single chain antibodies, Fab fragments, F(ab')<sub>2</sub> fragments, fragments produced by a Fab expression library, anti-idiotypic (anti-Id) antibodies, and epitope-binding fragments of any of the above. Such antibodies can be utilized in methods of treating cardiovascular disease.

Both polyclonal and monoclonal antibodies to IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 can be prepared by conventional techniques. See, for example, *Monoclonal Antibodies, Hybridomas: A New Dimension in Biological Analyses*, Kennet *et al.* (eds.), Plenum Press, New York (1980); and *Antibodies: A Laboratory Manual*, Harlow and Land (eds.), Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, (1988); Kohler and Milstein, (U.S. Pat. No. 4,376,110); the human B-cell hybridoma technique (Kosbor *et al.*, Immunology Today 4:72, 1983; Cole *et al.*, Proc. Natl. Acad. Sci. USA 80:2026, 1983); and the EBV-hybridoma technique (Cole *et al.*, 1985, Monoclonal Antibodies And Cancer Therapy, Alan R. Liss, Inc., pp. 77-96).

Methods of making humanized monoclonal antibodies are well known, and include for example those described in U.S. Pat. No. 5,585,089 (Protein Design: C L Queen *et al.*; "Humanized Immunoglobulins"), U.S. Pat. No. 5,565,332 ("Production of Chimeric Antibodies-A Combinatorial Approach"), U.S. Pat. No. 5,225,539 (Med Res Council: G P Winter; "Recombinant Altered Antibodies And Methods Of Making Altered Antibodies"), U.S. Pat. No. 5,693,761-762 (Protein Design: C L Queen *et al.*; "Polynucleotides Encoding Improved Humanized Immunoglobulins", and "Humanized Immunoglobulins"), and U.S. Pat. No. 5,530,101 (Protein Design: C L Queen *et al.*; "Humanized Immunoglobulins"), and references cited therein.

Hybridoma cell lines that produce monoclonal antibodies specific for IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39 are contemplated herein. Such hybridomas can be produced and identified by conventional techniques. For the production of antibodies, various host animals may be immunized by injection with IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 polypeptide that is immunogenic. Such host animals may include, but are not limited to, horse, goat, sheep, cow, rabbits, mice, and rats, to name a few. Various adjuvants may be used to increase the immunological response. Depending on the host species, such adjuvants include, but are not limited to, Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanin,

dinitrophenol, and potentially useful human adjuvants such as BCG (bacille Calmette-Guerin) and *Corynebacterium parvum*. The monoclonal antibodies can be recovered by conventional techniques. Such monoclonal antibodies may be of any immunoglobulin class including IgG, IgM, IgE, IgA, IgD, and any subclass thereof. The hybridoma producing the mAb may be cultivated *in vitro* or *in vivo*. Or, the antibody genes can be cloned and optionally otherwise altered, and expressed in another cell line approved for recombinant production of protein pharmaceuticals such as, for example, CHO cells.

Alternatively, libraries of antibody fragments can be screened and used to develop human antibodies through recombinant techniques. Such libraries are commercially available from, for example, Cambridge Antibody Technology (Melbourne, UK), and Morphosys (Munich, DE).

In addition, techniques developed for the production of "chimeric antibodies" (Takeda *et al.*, *Nature*, 314:452, 1985) by splicing the genes from a mouse antibody molecule of appropriate antigen specificity together with genes from a human antibody molecule of appropriate biological activity can be used. A chimeric antibody is a molecule in which different portions are derived from different animal species, such as those having a variable region derived from a porcine mAb and a human immunoglobulin constant region. The monoclonal antibodies of the invention also include humanized versions of murine monoclonal antibodies. Such humanized antibodies can be prepared by known techniques and offer the advantage of reduced immunogenicity when the antibodies are administered to humans. For example, transgenic mice into which genetic material encoding one or more human immunoglobulin chains has been introduced may be employed. Such mice may be genetically altered in a variety of ways. The genetic manipulation may result in human immunoglobulin polypeptide chains replacing endogenous immunoglobulin chains in at least some (preferably virtually all) antibodies produced by the animal upon immunization. Procedures for the production of chimeric and further engineered monoclonal antibodies include those described in Riechmann *et al.* (*Nature* 332:323, 1988), Liu *et al.* (*PNAS* 84:3439, 1987), Larrick *et al.* (*Bio/Technology* 7:934, 1989), and Winter and Harris (*TIPS* 14:139, Can, 1993). Procedures to generate antibodies transgenically can be found in GB 2,272,440, US Patent Nos. 5,569,825 and 5,545,806 and related patents claiming priority therefrom, all of which are incorporated by reference herein. For use in humans, the antibodies are typically human or humanized; techniques for creating such human antibodies are also known. Transgenic animals for making human antibodies are available from, for example, Medarex Inc. (Princeton, NJ) Protein Design Labs, Inc. (Fremont, CA) and Abgenix Inc. (Fremont, CA).

Expression of a humanized immunoglobulin sequences in bacterial hosts may be used to select higher affinity humanized immunoglobulin sequences by mutagenizing the CDR regions and producing bacteriophage display libraries which may be screened for humanized

immunoglobulin CDR variants which possess high affinity and/or high specificity binding to IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39. One potential advantage of such affinity sharpening is the generation of humanized immunoglobulin CDR variants that have improved binding affinity and/or reduced cross-reactivity with molecules other than the molecule to which they were raised. Methods for producing phage display libraries having immunoglobulin variable region sequences are provided in the art (see, *e.g.*, Cesareni, FEBS Lett 307:66, 1992; Swimmer *et al.*, Proc. Natl. Acad. Sci. USA 89:3756, 1992; Gram *et al.*, Proc. Natl. Acad. Sci. USA 89:3576, 1992; Clackson *et al.*, Nature 352:624, 1991; Scott & Smith, Science 249:386, 1990; Garrard *et al.*, Bio/Techniques 9:1373, 1991; which are incorporated herein by reference in their entirety for all purposes. The resultant affinity sharpened CDR variant humanized immunoglobulin sequences are subsequently expressed in a suitable host.

Antibody fragments, which recognize specific epitopes, may be generated by known techniques. For example, such fragments include but are not limited to: the F(ab')<sub>2</sub> fragments which can be produced by pepsin digestion of the antibody molecule and the Fab fragments which can be generated by reducing the disulfide bridges of the (ab')<sub>2</sub> fragments. Alternatively, Fab expression libraries may be constructed (Huse *et al.*, Science, 246:1275, 1989) to allow rapid and easy identification of monoclonal Fab fragments with the desired specificity. Techniques described for the production of single chain antibodies (U.S. Pat. No. 4,946,778; Bird, Science 242:423, 1988; Huston *et al.*, Proc. Natl. Acad. Sci. USA 85:5879, 1988; and Ward *et al.*, Nature 334:544, 1989) can also be adapted to produce single chain antibodies against polypeptides containing IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 amino acid sequences. In addition, antibodies to the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 polypeptides can, in turn, be utilized to generate anti-idiotypic antibodies using techniques known to those skilled in the art. (See, *e.g.*, Greenspan & Bona, FASEB J 7(5):437, 1993; and Nissinoff, J. Immunol. 147(8):2429, 1991).

#### **I. NUCLEIC ACID-BASED IL-17, IL-18, 4-1BB, CD30 and OX40 ANTAGONISTS**

In alternative embodiments, nucleic acid-based immuno therapy can be designed to reduce the level of endogenous IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 gene expression, *e.g.*, using antisense or ribozyme approaches to inhibit or prevent translation of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 mRNA transcripts; triple helix approaches to inhibit transcription of the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 gene; or targeted homologous



recombination to inactivate or "knock out" the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 gene or its endogenous promoter.

Antisense RNA and DNA molecules act to directly block the translation of mRNA by hybridizing to targeted mRNA and preventing polypeptide translation. Antisense approaches involve the design of oligonucleotides (either DNA or RNA) that are complementary to a mRNA having an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 polynucleotide sequence. Absolute complementarity, although preferred, is not required. A sequence "complementary" to a portion of RNA, as referred to herein, means a sequence having sufficient complementarity to be able to hybridize with the RNA, thereby forming a stable duplex. Oligonucleotides that are complementary to the 5' end of the message, *e.g.*, the 5' untranslated sequence up to and including the AUG initiation codon, should work most efficiently at inhibiting translation. However, oligonucleotides complementary to either the 5'- or 3'- non- translated, non-coding regions of the IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 gene transcript could be used in an antisense approach to inhibit translation of endogenous IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39. Oligonucleotides complementary to the 5' untranslated region of the mRNA should include the complement of the AUG start codon. Antisense nucleic acids should be at least six nucleotides in length, and are preferably oligonucleotides ranging from 6 to about 50 nucleotides in length. The oligonucleotides can be DNA or RNA or chimeric mixtures or derivatives or modified versions thereof, single-stranded or double-stranded. The oligonucleotide can be modified at the base moiety, sugar moiety, or phosphate backbone, for example, to improve stability of the molecule, hybridization, and the like. The oligonucleotide may include other appended groups such as peptides (*e.g.*, for targeting host cell receptors *in vivo*), or agents facilitating transport across the cell membrane (see, *e.g.*, Letsinger *et al.*, 1989, Proc. Natl. Acad. Sci. U.S.A. 86:6553-6556; Lemaitre *et al.*, 1987, Proc. Natl. Acad. Sci. 84:648-652; PCT Publication No. WO88/09810, published Dec. 15, 1988), or hybridization-triggered cleavage agents or intercalating agents (see, *e.g.*, Zon, 1988, Pharm. Res. 5:539-549).

The antisense molecules are delivered to cells, which express a transcript having an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 polynucleotide sequence *in vivo* by, for example, injecting directly into the tissue or cell derivation site, or by use of modified antisense molecules, designed to target the desired cells (*e.g.*, antisense linked to peptides or antibodies that specifically bind receptors or antigens expressed on the target cell surface) can be administered systemically. Another approach utilizes a recombinant DNA construct in which the antisense oligonucleotide is placed under the control of a strong pol III or pol II promoter. The use of such a construct to transfect target cells in the subject will result in the transcription of sufficient amounts of

single stranded RNAs that will form complementary base pairs with the endogenous IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 transcripts and thereby prevent translation of the IL-17 mRNA. For example, a vector can be introduced *in vivo* such that it is taken up by a cell and directs the transcription of an antisense RNA. Such a vector can remain episomal or become chromosomally integrated, so long as it can be transcribed to produce the desired antisense RNA. Vectors can be plasmid, viral, or others known in the art, used for replication and expression in mammalian cells.

Ribozyme molecules designed to catalytically cleave mRNA transcripts having an IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 polynucleotide sequence prevent translation of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 mRNA (see, *e.g.*, PCT International Publication WO90/11364, published Oct. 4, 1990; US Patent No. 5,824,519). Ribozymes are RNA molecules possessing the ability to specifically cleave other single-stranded RNA in a manner analogous to DNA restriction endonucleases. A major advantage of this approach is that, because they are sequence-specific, only mRNAs with particular sequences are inactivated. There are two basic types of ribozymes namely, tetrahymena-type (Hasselhoff, *Nature*, 334:585-591, 1988) and "hammerhead"-type. Tetrahymena-type ribozymes recognize sequences, which are four bases in length, while "hammerhead"-type ribozymes recognize base sequences 11-18 bases in length. The longer the recognition sequence, the greater the likelihood that the sequence will occur exclusively in the target mRNA species. Consequently, hammerhead-type ribozymes are preferable to tetrahymena-type ribozymes.

As in the antisense approach, the ribozymes can be composed of modified oligonucleotides (*e.g.* for improved stability, targeting, and the like). A typical method of delivery involves using a DNA construct "encoding" the ribozyme under the control of a strong constitutive pol III or pol II promoter, so that transfected cells will produce sufficient quantities of the ribozyme to destroy endogenous IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 message and inhibit translation. Because ribozymes, unlike antisense molecules, are catalytic, a lower intracellular concentration is required for efficiency.

Alternatively, endogenous IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 expression can be reduced by targeting deoxyribonucleotide sequences complementary to the regulatory region of the target gene (*i.e.*, the target gene promoter and/or enhancers) to form triple helical structures that prevent transcription of the target IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 gene (see generally, Helene, 1991, *Anticancer Drug Des.*, 6(6), 569-584; Helene, *et al.*, 1992, *Ann. N.Y. Acad. Sci.*, 660, 27-36; and Maher, 1992, *Bioassays* 14(12), 807-815).

Antisense RNA and DNA, ribozyme, and triple helix molecules of the invention may be prepared by any method known in the art for the synthesis of DNA and RNA molecules and include techniques for chemically synthesizing oligodeoxyribonucleotides and oligoribonucleotides such as, for example, solid phase phosphoramidite chemical synthesis, *e.g.* by use of an automated DNA synthesizer (such as are commercially available from Biosearch, Applied Biosystems, and the like). As examples, phosphorothioate oligonucleotides may be synthesized by the method of Stein *et al.*, 1988, Nucl. Acids Res. 16:3209. Methylphosphonate oligonucleotides can be prepared by use of controlled pore glass polymer supports (Sarin *et al.*, 1988, Proc. Natl. Acad. Sci. U.S.A. 85:7448-7451). Alternatively, RNA molecules may be generated by *in vitro* and *in vivo* transcription of DNA sequences encoding the antisense RNA molecule. Such DNA sequences may be incorporated into a wide variety of vectors that incorporate suitable RNA polymerase promoters such as the T7 or SP6 polymerase promoters. Alternatively, antisense cDNA constructs that synthesize antisense RNA constitutively or inducibly, depending on the promoter used, can be introduced stably into cell lines.

In alternative embodiments IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 expression may be blocked by post-translational gene silencing, such as by double-stranded RNA-induced gene silencing, also known as RNA interference (RNAi). RNA sequences of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 may be modified to provide double-stranded sequences or short hairpin RNAs for therapeutic use.

#### **J. SCREENING FOR IL-17, IL-18, 4-1BB, CD30 and OX40 ANTAGONISTS**

IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists can be evaluated using screening assays known in the art, such as high throughput test systems. The assays can be performed in a variety of formats, including protein-protein binding assays, competition binding assays, biochemical screening assays, immunoassays, cell based assays, etc. For the sake of clarity, the following examples describe exemplary assays in the context of IL-17 and IL-17R and are therefore illustrative and not limiting. The same assay formats and underlying rationale are equally applicable to IL-18:IL-18R, 4-1BB-L:4-1BB, CD30-L:CD30 and OX40-L:OX40 interactions for screening for respective antagonists.

By observing the effect that an IL-17 antagonist has on the interaction between IL-17 and IL-17 receptor in various binding assays, on IL-17/IL-17 receptor-mediated activity in functional tests, and in cell based screens, molecules that are potential therapeutics are identified because they inhibit the interaction between IL-17 and IL-17 receptor. IL-17 antagonists that partially or completely inhibit IL-17 binding to IL-17 receptor, and hence the activation of IL-17 receptor, can be useful as immunosuppressants or anti-inflammatory agents in the treatment of cardiovascular disease.

One embodiment of a screening assay that can be used to screen IL-17 antagonists for their ability to inhibit the interaction of IL-17 and IL-17 receptor comprises the steps of forming a composition comprising an IL-17 protein, an IL-17 receptor protein, and the test compound (i.e., a putative IL-17 antagonist); assaying for the level of interaction of the IL-17 protein, an IL-17 receptor protein; and comparing the level obtained in the presence of the test compound to that obtained in the absence of the test compound, such that if the level obtained differs, a compound that affects the interaction of IL-17 and IL-17 receptor is identified. In alternative embodiments, at least one of the IL-17 or IL-17 receptor can be labeled with a detectable moiety. In alternative embodiments, one of the IL-17 or IL-17 receptor can be soluble, and the other can be bound, although alternative assay formats are possible and well known. The test compound can be added to the composition after addition of the IL-17 and IL-17 receptor, before both proteins are added, or after one protein is added and before the other is added.

In another aspect, the screening methods comprise forming a composition comprising the test compound, the IL-17 protein and cells expressing IL-17 receptor; determining the level of biological activity of IL-17 on the IL-17 receptor in the composition; and comparing the level of biological activity with that which occurs in the absence of test compound, wherein a difference in the level of biological activity indicates that the test compound affects the biological activity of the IL-17/IL-17 receptor complex. Biological activity of IL-17 on the IL-17 receptor can be assayed in any number of ways, for example but not limited to, determining the phosphorylation state of intracellular proteins (i.e., activation of the IL-17 receptor by IL-17); determining the production of proinflammatory factors, such as IL-6, IL-8, monocyte chemoattractant protein-1 and Gro $\alpha$ ; determining the production of hematopoietic cytokines, such as G-CSF and GM-CSF and IL-8; and determining increased expression of IL-1 $\beta$  and TNF- $\alpha$ , as well as measuring induction of iNOS in macrophages.

A particular example of an assay for the identification of potential IL-17 antagonists is a competitive assay, which combines IL-17 and an IL-17 receptor-specific antagonist with IL-17 receptor under the appropriate conditions for a competitive assay. Either IL-17 or the IL-17 receptor-specific antagonist can be labeled so that the binding can be measured and the effectiveness of the antagonist judged. The label allows for detection by direct or indirect means. Direct means include, but are not limited to luminescence, radioactivity, optical or electron density. Indirect means include but are not limited to an enzyme or epitope tag.

Another method by which IL-17 antagonists can be identified that inhibit the interaction between IL-17 and IL-17 receptor is the solid phase method, in which IL-17 receptor is bound and placed in a medium with labeled IL-17. The amount of signal produced by the interaction between IL-17 and IL-17 receptor is measured in the presence and in the absence of a test compound. Diminished levels of signal, in comparison to a control, indicate that the test compound inhibited the interaction between IL-17 and IL-17

receptor. Increased levels of signal, in comparison to a control, indicate that the candidate molecule promotes the interaction between IL-17 and IL-17 receptor. In alternative embodiments, IL-17 could be bound and IL-17 receptor labeled. The IL-17 antagonist, IL-17 receptor and/or IL-17 proteins can be directly or indirectly labeled. For example, if the protein is recombinantly produced, one can engineer fusion proteins that can facilitate solubility, labeling, immobilization and/or detection. Fusion proteins which facilitate these processes can include, but are not limited to soluble Ig-tailed fusion proteins and His-tagged proteins. Methods for engineering such soluble Ig-tailed fusion proteins are well known to those of skill in the art. See, for example, U.S. Pat. No. 5,116,964, and the illustrative embodiments described below. Indirect labeling involves the use of a protein, such as a labeled antibody, which specifically binds to a component of the assay.

IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists can be identified and evaluated using cells and/or cell lines derived from heart and vascular tissues. For example, cardiomyocyte cells and cell lines may be used to evaluate IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists in any of the suitable assays described herein. Biologically relevant readouts in the cardiomyocyte-based assay (or other cells) may be used to evaluate potential antagonists, such as cell survival; hypertrophic responses; and/or production of ANP and/or BNP in response to hypoxic or environmental stress.

IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists can also be identified using methods that are well suited for high-throughput screening procedures, such as scintillation proximity assays (Udenfriend *et al.*, 1985, *Proc Natl Acad Sci USA* 82: 8672-8676), yeast two-hybrid or interaction trap assays, homogeneous time-resolved fluorescence methods (Park *et al.*, 1999, *Anal Biochem* 269: 94-104), fluorescence resonance energy transfer (FRET) methods (Clegg RM, 1995, *Curr Opin Biotechnol* 6: 103-110), or methods that measure any changes in surface plasmon resonance when a bound polypeptide is exposed to a potential binding partner, using for example a biosensor such as that supplied by Biacore AB (Uppsala, Sweden).

Compounds that can be assayed that may also be IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists include but are not limited to small organic molecules, such as those that are commercially available - often as part of large combinatorial chemistry compound 'libraries' - from companies such as Sigma-Aldrich (St. Louis, MO), Arqule (Woburn, MA), Enzymed (Iowa City, IA), Maybridge Chemical Co.(Trevillet, Cornwall, UK), MDS Panlabs (Bothell, WA), Pharmacopeia (Princeton, NJ), and Trega (San Diego, CA). Preferred small organic molecules for screening using these assays are usually less than 10K molecular weight and can possess a number of physicochemical and pharmacological properties which enhance cell penetration, resist degradation, and/or prolong their physiological half-lives (Gibbs, J., 1994, *Pharmaceutical Research in Molecular Oncology, Cell* 79(2): 193-198). Compounds including natural products, inorganic chemicals, and biologically active

materials such as proteins and toxins can also be assayed using these methods for the ability to bind to serve as IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists.

Antagonizing IL-17:IL-17R, IL-18:IL-18R, 4-1BB-L:4-1BB, CD30-L:CD30 and/or OX40-L:OX40 interactions and therefore intercellular communication, cell stimulation, or immune cell activity can be manipulated by IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists to control these activities in target cells. For example, IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists or nucleic acids encoding IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists can be administered to a cell or group of cells to block IL-17:IL-17R, IL-18:IL-18R, 4-1BB-L:4-1BB, CD30-L:CD30 and/or OX40-L:OX40 binding and thereby suppress or arrest cellular communication, cell stimulation, or activity in the target cells. In such an assay, one would determine a rate of communication or cell stimulation in the presence of the IL-17:IL-17R, IL-18:IL-18R, 4-1BB-L:4-1BB, CD30-L:CD30 and/or OX40-L:OX40 binding and then determine if such communication or cell stimulation is altered in the presence of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists. Exemplary assays for this aspect of the invention include cytokine secretion assays, T-cell co-stimulation assays, and mixed lymphocyte reactions involving antigen presenting cells and T cells. These assays are well known to those skilled in the art.

IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists may regulate cytokine, cell proliferation (either inducing or inhibiting), or cell differentiation (either inducing or inhibiting) activity, or may induce production of other cytokines in certain cell populations. Many polypeptide factors discovered to date have exhibited such activity in one or more factor-dependent cell proliferation assays, and hence the assays serve as a convenient confirmation of cell stimulatory activity. The activity of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists may be evidenced by any one of a number of routine factor-dependent cell proliferation assays for cell lines including, without limitation, NF $\kappa$ B, 32D, DA2, DA1G, T10, B9, B9/11, BaF3, MC9/G, M+ (preB M+), 2E8, RB5, DA1, 123, T1165, HT2, CTLL2, TF-1, Mo7e and CMK.

The activity of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists may, among other means, be measured by the following methods:

Assays for receptor-ligand activity include without limitation those described in: *Current Protocols in Immunology* Coligan *et al.* eds, Greene Publishing Associates and Wiley-Interscience (Chapter 7.28, Measurement of cellular adhesion under static conditions 7.28.1-7.28.22), Takai *et al.*, *PNAS USA* 84:6864-6868, 1987; Bierer *et al.*, *J. Exp. Med.* 168:1145-1156, 1988; Rosenstein *et al.*, *J. Exp. Med.* 169:149-160 1989; Stoltenborg *et al.*, *J. Immunol. Methods* 175:59-68, 1994; Stitt *et al.*, *Cell* 80:661-670, 1995.

Assays for T-cell or thymocyte proliferation include without limitation those described in: *Current Protocols in Immunology*, Coligan *et al.* eds, Greene Publishing Associates and Wiley-Interscience (pp. 3.1-3.19: *In vitro* assays for mouse lymphocyte

function; Chapter 7: Immunologic studies in humans); Takai *et al.*, *J. Immunol.* 137: 3494-3500, 1986; Bertagnolli *et al.*, *J. Immunol.* 145: 1706-1712, 1990; Bertagnolli *et al.*, *Cellular Immunology* 133:327-341, 1991; Bertagnolli, *et al.*, *J. Immunol.* 149:3778-3783, 1992; Bowman *et al.*, *J. Immunol.* 152: 1756-1761, 1994.

- 5 Assays for cytokine production and/or proliferation of spleen cells, lymph node cells or thymocytes include, without limitation, those described in: Kruisbeek and Shevach, 1994, Polyclonal T cell stimulation, in *Current Protocols in Immunology*, Coligan *et al.* eds. Vol 1 pp. 3.12.1-3.12.14, John Wiley and Sons, Toronto; and Schreiber, 1994, Measurement of mouse and human interferon gamma in *Current Protocols in Immunology*, Coligan *et al.* eds. Vol 1 pp. 6.8.1-6.8.8, John Wiley and Sons, Toronto.

- 10 Assays for proliferation and differentiation of hematopoietic and lymphopoietic cells include, without limitation, those described in: Bottomly *et al.*, 1991, Measurement of human and murine interleukin 2 and interleukin 4, in *Current Protocols in Immunology*, Coligan *et al.* eds. Vol 1 pp. 6.3.1-6.3.12, John Wiley and Sons, Toronto; deVries *et al.*, *J Exp Med* 173: 1205-1211, 1991; Moreau *et al.*, *Nature* 336:690-692, 1988; Greenberger *et al.*, *Proc Natl Acad Sci USA* 80: 2931-2938, 1983; Nordan, 1991, Measurement of mouse and human interleukin 6, in *Current Protocols in Immunology* Coligan *et al.* eds. Vol 1 pp. 6.6.1-6.6.5, John Wiley and Sons, Toronto; Smith *et al.*, *Proc Natl Acad Sci USA* 83: 1857-1861, 1986; Bennett *et al.*, 1991, Measurement of human interleukin 11, in *Current Protocols in Immunology* Coligan *et al.* eds. Vol 1 pp. 6.15.1 John Wiley and Sons, Toronto; Ciarletta *et al.*, 1991, Measurement of mouse and human Interleukin 9, in *Current Protocols in Immunology*; Coligan *et al.* eds. Vol 1 pp. 6.13.1, John Wiley and Sons, Toronto.

- 20 Assays for T-cell clone responses to antigens (which will identify, among others, polypeptides that affect APC-T cell interactions as well as direct T-cell effects by measuring proliferation and cytokine production) include, without limitation, those described in: *Current Protocols in Immunology*, Coligan *et al.* eds, Greene Publishing Associates and Wiley-Interscience (Chapter 3: *In vitro* assays for mouse lymphocyte function; Chapter 6: Cytokines and their cellular receptors; Chapter 7: Immunologic studies in humans); Weinberger *et al.*, *PNAS USA* 77: 6091-6095, 1980; Weinberger *et al.*, *Eur. J. Immun.* 11:405-411, 1981; Takai *et al.*, *J. Immunol.* 137:3494-3500, 1986; Takai *et al.*, *J. Immunol.* 140:508-512, 1988

- 30 Assays for thymocyte or splenocyte cytotoxicity include, without limitation, those described in: *Current Protocols in Immunology*, Coligan *et al.* eds, Greene Publishing Associates and Wiley-Interscience (Chapter 3, *In Vitro* assays for Mouse Lymphocyte Function 3.1-3.19; Chapter 7, Immunologic studies in Humans); Herrmann *et al.*, *PNAS USA* 78:2488-2492, 1981; Herrmann *et al.*, *J. Immunol.* 128:1968-1974, 1982; Handa *et al.*, *J. Immunol.* 135:1564-1572, 1985; Takai *et al.*, *J. Immunol.* 137:3494-3500, 1986; Takai *et al.*, *J. Immunol.* 140:508-512, 1988; Herrmann *et al.*, *PNAS USA* 78:2488-2492, 1981; Herrmann *et al.*, *J. Immunol.* 128:1968-1974, 1982; Handa *et al.*, *J. Immunol.* 135:1564-1572, 1985;

Takai *et al.*, *J. Immunol.* 137:3494-3500, 1986; Bowman *et al.*, *J. Virology* 61:1992-1998; Takai *et al.*, *J. Immunol.* 140:508-512, 1988; Bertagnolli *et al.*, *Cellular Immunology* 133:327-341, 1991; Brown *et al.*, *J. Immunol.* 153:3079-3092, 1994.

Assays for T-cell-dependent immunoglobulin responses and isotype switching (which will identify, among others, polypeptides that modulate T-cell dependent antibody responses and that affect Th1/Th2 profiles) include, without limitation, those described in: Maliszewski, *J Immunol* 144: 3028-3033, 1990; and Mond and Brunswick, 1994, Assays for B cell function: *in vitro* antibody production, in *Current Protocols in Immunology* Coligan *et al.* eds. Vol 1 pp. 3.8.1-3.8.16, John Wiley and Sons, Toronto.

Mixed lymphocyte reaction (MLR) assays (which will identify, among others, polypeptides that generate predominantly Th1 and CTL responses) include, without limitation, those described in: *Current Protocols in Immunology*, Coligan *et al.* eds, Greene Publishing Associates and Wiley-Interscience (Chapter 3, In Vitro assays for Mouse Lymphocyte Function 3.1-3.19; Chapter 7, Immunologic studies in Humans); Takai *et al.*, *J. Immunol.* 137:3494-3500, 1986; Takai *et al.*, *J. Immunol.* 140:508-512, 1988; Bertagnolli *et al.*, *J. Immunol.* 149:3778-3783, 1992.

Dendritic cell-dependent assays (which will identify, among others, polypeptides expressed by dendritic cells that activate naive T-cells) include, without limitation, those described in: Guery *et al.*, *J. Immunol* 134:536-544, 1995; Inaba *et al.*, *J Exp Med* 173:549-559, 1991; Macatonia *et al.*, *J Immunol* 154:5071-5079, 1995; Porgador *et al.*, *J Exp Med* 182:255-260, 1995; Nair *et al.*, *J Virology* 67:4062-4069, 1993; Huang *et al.*, *Science* 264:961-965, 1994; Macatonia *et al.*, *J Exp Med* 169:1255-1264, 1989; Bhardwaj *et al.*, *J Clin Invest* 94:797-807, 1994; and Inaba *et al.*, *J Exp Med* 172:631-640, 1990.

Assays for lymphocyte survival/apoptosis (which will identify, among others, polypeptides that prevent apoptosis after superantigen induction and polypeptides that regulate lymphocyte homeostasis) include, without limitation, those described in: Darzynkiewicz *et al.*, *Cytometry* 13:795-808, 1992; Gorczyca *et al.*, *Leukemia* 7:659-670, 1993; Gorczyca *et al.*, *Cancer Research* 53:1945-1951, 1993; Itoh *et al.*, *Cell* 66:233-243, 1991; Zacharchuk, *J Immunol* 145:4037-4045, 1990; Zamai *et al.*, *Cytometry* 14:891-897, 1993; Gorczyca *et al.*, *International Journal of Oncology* 1:639-648, 1992.

Assays for polypeptides that influence early steps of T-cell commitment and development include, without limitation, those described in: Antica *et al.*, *Blood* 84:111-117, 1994; Fine *et al.*, *Cell Immunol* 155:111-122, 1994; Galy *et al.*, *Blood* 85:2770-2778, 1995; Toki *et al.*, *PNAS USA* 88:7548-7551, 1991

Assays for embryonic stem cell differentiation (which will identify, among others, polypeptides that influence embryonic differentiation hematopoiesis) include, without limitation, those described in: Johansson *et al.* *Cellular Biology* 15:141-151, 1995; Keller *et*



*al.*, *Molecular and Cellular Biology* 13:473-486, 1993; *McClanahan et al.*, *Blood* 81:2903-2915, 1993.

Assays for cell movement and adhesion include, without limitation, those described in: *Current Protocols in Immunology* Coligan *et al.* eds, Greene Publishing Associates and Wiley-Interscience (Chapter 6.12, Measurement of alpha and beta chemokines 6.12.1-6.12.28); Taub *et al.* *J. Clin. Invest.* 95:1370-1376, 1995; Lind *et al.* *APMIS* 103:140-146, 1995; Muller *et al.* *Eur. J. Immunol.* 25: 1744-1748; Gruber *et al.* *J Immunol.* 152:5860-5867, 1994; Johnston *et al.* *J Immunol.* 153: 1762-1768, 1994

Assay for hemostatic and thrombolytic activity include, without limitation, those described in: Linet *et al.*, *J. Clin. Pharmacol.* 26:131-140, 1986; Burdick *et al.*, *Thrombosis Res.* 45:413-419, 1987; Humphrey *et al.*, *Fibrinolysis* 5:71-79 (1991); Schaub, *Prostaglandins* 35:467-474, 1988.

## II. THERAPEUTIC COMPOSITIONS AND ADMINISTRATION THEREOF

This invention provides compounds, compositions, and methods for treating a subject, preferably a human patient, who is suffering from cardiovascular disease. The terms "treat", "treating", and "treatment" used herein includes curative, preventative (*e.g.*, prophylactic) and palliative or ameliorative treatment. Therapeutic compositions of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 may therefore need to be administered before, during, or after the presentation of symptoms. For therapeutic use, a soluble IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 is administered to a subject for treatment in a manner appropriate to the indication.

Embodiments of the invention include therapeutic compositions (also referred to as pharmaceutical compositions) comprising one or more soluble IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists and/or CD39. A "therapeutic composition," as used herein, comprises one or more soluble IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists and/or CD39 and a pharmaceutically acceptable diluent, preservative, solubilizer, emulsifier, adjuvant and/or carrier. As used herein, the terms "pharmaceutically" acceptable and "physiologically" acceptable are used interchangeably. The term "pharmaceutically acceptable" means a non-toxic material that does not interfere with the effectiveness of the biological activity of the active ingredient(s).

Therefore, therapeutic compositions comprise all of the antagonists described in the sections above: *e.g.*, soluble receptor molecules, ligands and/or binding proteins, such as IL-17, IL-17R, IL-18, IL-18R, IL-18 binding protein (IL-18BP), 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39, as well as biologically active fragments, muteins, variants, derivatives, fusions, etc. thereof; antibodies, fusion proteins and/or peptibodies directed against one or more of the following: IL-17, IL-17R, IL-18, IL-18R, IL-18 binding protein (IL-18BP), 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L and CD39; small

molecules, such as peptidomimetics, mimotopes and the like, that antagonize the interaction between IL-17 and IL-17R, IL-18 and IL-18R, CD30-L and CD30, 4-1BB-L and 4-1BB and/or OX40-L and OX40; antisense oligonucleotides that specifically target and hybridize to the mRNA of endogenous IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 to inhibit or prevent translation of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39 mRNA transcripts; and RNA-interference molecules tailored to silence expression of IL-17, IL-17R, IL-18, IL-18R, IL-18BP, 4-1BB, 4-1BB-L, CD30, CD30-L, OX40, OX40-L or CD39.

Physiologically acceptable carriers, excipients or diluents are nontoxic to recipients at the dosages and concentrations employed. Ordinarily, preparing such compositions entails combining the IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 with buffers, antioxidants such as ascorbic acid, low molecular weight polypeptides (such as those having fewer than 10 amino acids), proteins, amino acids, carbohydrates such as glucose, sucrose or dextrans, chelating agents such as EDTA, glutathione and other stabilizers and excipients. Neutral buffered saline or saline mixed with conspecific serum albumin are exemplary appropriate diluents. The IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 preferably is formulated as a lyophilizate using appropriate excipient solutions (e.g., sucrose) as diluents. Appropriate dosages can be determined in standard dosing trials, and may vary according to the chosen route of administration. In accordance with appropriate industry standards, preservatives may also be added, such as benzyl alcohol. The amount and frequency of administration will depend, of course, on such factors as the nature and severity of the indication being treated, the desired response, the age and condition of the patient, and so forth

In one embodiment, sustained-release forms of soluble IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 described herein, are used. Sustained-release forms suitable for use in the disclosed methods include, but are not limited to, IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39, that is encapsulated in a slowly-dissolving biocompatible polymer, admixed with such a polymer, and or encased in a biocompatible semi-permeable implant. In addition, the IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 may be conjugated with polyethylene glycol (pegylated) to prolong its serum half-life or to enhance protein delivery (as described in detail above).

One type of sustained release technology that may be used in administering soluble IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 therapeutic compositions is that utilizing hydrogel materials, for example, photopolymerizable hydrogels (Sawhney et al., *Macromolecules* 26:581; 1993). Similar hydrogels have been used to prevent postsurgical adhesion formation (Hill-West et al., *Obstet. Gynecol.* 83:59, 1994) and to prevent thrombosis and vessel narrowing following vascular injury (Hill-West et al., *Proc. Natl. Acad. Sci. USA* 91:5967, 1994). Polypeptides can be incorporated into such hydrogels to

provide sustained, localized release of active agents (West and Hubbel, *Reactive Polymers* 25:139, 1995; Hill-West et al., *J. Surg. Res.* 58:759; 1995). The sustained, localized release of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 when incorporated into hydrogels would be amplified by the long half life of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39.

Therapeutic compositions may be for administration for injection, or for oral, pulmonary, nasal, transdermal or other forms of administration. In general, the invention encompasses therapeutic compositions comprising effective amounts one or more IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 together with pharmaceutically acceptable diluents, preservatives, solubilizers, emulsifiers, adjuvants and/or carriers. Such compositions include diluents of various buffer content (e.g., Tris-HCl, acetate, phosphate), pH and ionic strength; additives such as detergents and solubilizing agents (e.g., Tween 80, Polysorbate 80), anti-oxidants (e.g., ascorbic acid, sodium metabisulfite), preservatives (e.g., Thimersol, benzyl alcohol) and bulking substances (e.g., lactose, mannitol); incorporation of the material into particulate preparations of polymeric compounds such as polylactic acid, polyglycolic acid, etc. or into liposomes. Hyaluronic acid may also be used, and this may have the effect of promoting sustained duration in the circulation. Such compositions may influence the physical state, stability, rate of in vivo release, and rate of in vivo clearance of the present proteins and derivatives. See, e.g., *Remington's Pharmaceutical Sciences*, 18th Ed. (1990, Mack Publishing Co., Easton, PA 18042) pages 1435-1712 which are herein incorporated by reference in their entirety. The compositions may be prepared in liquid form, or may be in dried powder, such as lyophilized form. Implantable sustained release formulations are also contemplated, as are transdermal formulations.

Contemplated for use herein are oral solid dosage forms, which are described generally in Chapter 89 of *Remington's Pharmaceutical Sciences* (1990), 18th Ed., Mack Publishing Co. Easton PA 18042, which is herein incorporated by reference in its entirety. Solid dosage forms include tablets, capsules, pills, troches or lozenges, cachets or pellets. Also, liposomal or proteinoid encapsulation may be used to formulate the present compositions (as, for example, proteinoid microspheres reported in U.S. Patent No. 4,925,673). Liposomal encapsulation may be used and the liposomes may be derivatized with various polymers (e.g., U.S. Patent No. 5,013,556). A description of possible solid dosage forms for the therapeutic is given in Chapter 10 of Marshall, K., *Modern Pharmaceutics* (1979), edited by G. S. Banker and C. T. Rhodes, herein incorporated by reference in its entirety. In general, the formulation will include one or more IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39, and inert ingredients which allow for protection against the stomach environment, and release of the biologically active material in the intestine.

Also specifically contemplated are oral dosage forms of the above inventive compounds. If necessary, the compounds may be chemically modified so that oral delivery is efficacious. Generally, the chemical modification contemplated is the attachment of at least one moiety to the compound molecule itself, where said moiety permits (a) inhibition of proteolysis; and (b) uptake into the blood stream from the stomach or intestine. Also desired is the increase in overall stability of the compound and increase in circulation time in the body. Moieties useful as covalently attached vehicles in this invention may also be used for this purpose. Examples of such moieties include: PEG, copolymers of ethylene glycol and propylene glycol, carboxymethyl cellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone and polyproline. See, for example, Abuchowski and Davis, *Soluble Polymer-Enzyme Adducts, Enzymes as Drugs* (1981), Hocenberg and Roberts, eds., Wiley-Interscience, New York, NY, , pp. 367-83; Newmark, *et al.* (1982), *J. Appl. Biochem.* 4:185-9. Other polymers that could be used are poly-1,3-dioxolane and poly-1,3,6-tioxocane. Preferred for pharmaceutical usage, as indicated above, are PEG moieties. For oral delivery dosage forms, it is also possible to use a salt of a modified aliphatic amino acid, such as sodium N-(8-[2-hydroxybenzoyl] amino) caprylate (SNAC), as a carrier to enhance absorption of the therapeutic compounds of this invention. The clinical efficacy of a heparin formulation using SNAC has been demonstrated in a Phase II trial conducted by Emisphere Technologies. See US Patent No. 5,792,451, "Oral drug delivery composition and methods".

The compounds of this invention can be included in the formulation as fine multiparticulates in the form of granules or pellets of particle size about 1 mm. The formulation of the material for capsule administration could also be as a powder, lightly compressed plugs or even as tablets. The therapeutic could be prepared by compression.

Colorants and flavoring agents may all be included. For example, the protein (or derivative) may be formulated (such as by liposome or microsphere encapsulation) and then further contained within an edible product, such as a refrigerated beverage containing colorants and flavoring agents.

One may dilute or increase the volume of the compound of the invention with an inert material. These diluents could include carbohydrates, especially mannitol,  $\alpha$ -lactose, anhydrous lactose, cellulose, sucrose, modified dextrans and starch. Certain inorganic salts may also be used as fillers including calcium triphosphate, magnesium carbonate and sodium chloride. Some commercially available diluents are Fast-Flo, Emdex, STA-Rx 1500, Emcompress and Avicell.

Disintegrants may be included in the formulation of the therapeutic into a solid dosage form. Materials used as disintegrants include but are not limited to starch including the commercial disintegrant based on starch, Explotab. Sodium starch glycolate, Amberlite, sodium carboxymethylcellulose, ultramylopectin, sodium alginate, gelatin, orange peel, acid carboxymethyl cellulose, natural sponge and bentonite may all be used. Another form of the

disintegrants are the insoluble cationic exchange resins. Powdered gums may be used as disintegrants and as binders and these can include powdered gums such as agar, Karaya or tragacanth. Alginic acid and its sodium salt are also useful as disintegrants.

Binders may be used to hold the therapeutic agent together to form a hard tablet and include materials from natural products such as acacia, tragacanth, starch and gelatin. Others include methyl cellulose (MC), ethyl cellulose (EC) and carboxymethyl cellulose (CMC). Polyvinyl pyrrolidone (PVP) and hydroxypropylmethyl cellulose (HPMC) could both be used in alcoholic solutions to granulate the therapeutic.

An antifrictional agent may be included in the formulation of the therapeutic to prevent sticking during the formulation process. Lubricants may be used as a layer between the therapeutic and the die wall, and these can include but are not limited to; stearic acid including its magnesium and calcium salts, polytetrafluoroethylene (PTFE), liquid paraffin, vegetable oils and waxes. Soluble lubricants may also be used such as sodium lauryl sulfate, magnesium lauryl sulfate, polyethylene glycol of various molecular weights, Carbowax 4000 and 6000.

Glidants that might improve the flow properties of the drug during formulation and to aid rearrangement during compression might be added. The glidants may include starch, talc, pyrogenic silica and hydrated silicoaluminate.

To aid dissolution of the compound of this invention into the aqueous environment a surfactant might be added as a wetting agent. Surfactants may include anionic detergents such as sodium lauryl sulfate, dioctyl sodium sulfosuccinate and dioctyl sodium sulfonate. Cationic detergents might be used and could include benzalkonium chloride or benzethonium chloride. The list of potential nonionic detergents that could be included in the formulation as surfactants are lauromacrogol 400, polyoxyl 40 stearate, polyoxyethylene hydrogenated castor oil 10, 50 and 60, glycerol monostearate, polysorbate 40, 60, 65 and 80, sucrose fatty acid ester, methyl cellulose and carboxymethyl cellulose. These surfactants could be present in the formulation of the protein or derivative either alone or as a mixture in different ratios.

Additives may also be included in the formulation to enhance uptake of the compound. Additives potentially having this property are for instance the fatty acids oleic acid, linoleic acid and linolenic acid.

Controlled release formulation may be desirable. The compound of this invention could be incorporated into an inert matrix which permits release by either diffusion or leaching mechanisms; e.g., gums. Slowly degenerating matrices may also be incorporated into the formulation, e.g., alginates, polysaccharides. Another form of a controlled release of the compounds of this invention is by a method based on the Oros therapeutic system (Alza Corp.), i.e., the drug is enclosed in a semipermeable membrane which allows water to enter and push drug out through a single small opening due to osmotic effects. Some enteric coatings also have a delayed release effect.

Other coatings may be used for the formulation. These include a variety of sugars which could be applied in a coating pan. The therapeutic agent could also be given in a film coated tablet and the materials used in this instance are divided into 2 groups. The first are the nonenteric materials and include methyl cellulose, ethyl cellulose, hydroxyethyl cellulose, methylhydroxy-ethyl cellulose, hydroxypropyl cellulose, hydroxypropyl-methyl cellulose, sodium carboxy-methyl cellulose, providone and the polyethylene glycols. The second group consists of the enteric materials that are commonly esters of phthalic acid.

A mix of materials might be used to provide the optimum film coating. Film coating may be carried out in a pan coater or in a fluidized bed or by compression coating.

Also contemplated herein is pulmonary delivery of the present protein (or derivatives thereof). The protein (or derivative) is delivered to the lungs of a mammal while inhaling and traverses across the lung epithelial lining to the blood stream. (Other reports of this include Adjei *et al.*, *Pharma. Res.* (1990) 7: 565-9; Adjei *et al.* (1990), *Internatl. J. Pharmaceutics* 63: 135-44 (leuprolide acetate); Braquet *et al.* (1989), *J. Cardiovasc. Pharmacol.* 13 (suppl.5): s.143-146 (endothelin-1); Hubbard *et al.* (1989), *Annals Int. Med.* 3: 206-12 ( $\alpha$ 1-antitrypsin); Smith *et al.* (1989), *J. Clin. Invest.* 84: 1145-6 ( $\alpha$ 1-proteinase); Oswein *et al.* (March 1990), "Aerosolization of Proteins", *Proc. Symp. Resp. Drug Delivery II*, Keystone, Colorado (recombinant human growth hormone); Debs *et al.* (1988), *J. Immunol.* 140: 3482-8 (interferon- $\gamma$  and tumor necrosis factor  $\alpha$ ) and Platz *et al.*, U.S. Patent No. 5,284,656 (granulocyte colony stimulating factor).

Contemplated for use in the practice of this invention are a wide range of mechanical devices designed for pulmonary delivery of therapeutic products, including but not limited to nebulizers, metered dose inhalers, and powder inhalers, all of which are familiar to those skilled in the art. Some specific examples of commercially available devices suitable for the practice of this invention are the Ultravent nebulizer, manufactured by Mallinckrodt, Inc., St. Louis, Missouri; the Acorn II nebulizer, manufactured by Marquest Medical Products, Englewood, Colorado; the Ventolin metered dose inhaler, manufactured by Glaxo Inc., Research Triangle Park, North Carolina; and the Spinhaler powder inhaler, manufactured by Fisons Corp., Bedford, Massachusetts.

All such devices require the use of formulations suitable for the dispensing of the inventive compound. Typically, each formulation is specific to the type of device employed and may involve the use of an appropriate propellant material, in addition to diluents, adjuvants and/or carriers useful in therapy.

The inventive compound should most advantageously be prepared in particulate form with an average particle size of less than 10  $\mu$ m (or microns), most preferably 0.5 to 5  $\mu$ m, for most effective delivery to the distal lung.

Pharmaceutically acceptable carriers include carbohydrates such as trehalose, mannitol, xylitol, sucrose, lactose, and sorbitol. Other ingredients for use in formulations may

include DPPC, DOPE, DSPC and DOPC. Natural or synthetic surfactants may be used. PEG may be used (even apart from its use in derivatizing the protein or analog). Dextran, such as cyclodextran, may be used. Bile salts and other related enhancers may be used. Cellulose and cellulose derivatives may be used. Amino acids may be used, such as use in a buffer formulation.

Also, the use of liposomes, microcapsules or microspheres, inclusion complexes, or other types of carriers is contemplated.

Formulations suitable for use with a nebulizer, either jet or ultrasonic, will typically comprise the inventive compound dissolved in water at a concentration of about 0.1 to 25 mg of biologically active protein per mL of solution. The formulation may also include a buffer and a simple sugar (e.g., for protein stabilization and regulation of osmotic pressure). The nebulizer formulation may also contain a surfactant, to reduce or prevent surface induced aggregation of the protein caused by atomization of the solution in forming the aerosol.

Formulations for use with a metered-dose inhaler device will generally comprise a finely divided powder containing the inventive compound suspended in a propellant with the aid of a surfactant. The propellant may be any conventional material employed for this purpose, such as a chlorofluorocarbon, a hydrochlorofluorocarbon, a hydrofluorocarbon, or a hydrocarbon, including trichlorofluoromethane, dichlorodifluoromethane, dichlorotetrafluoroethanol, and 1,1,1,2-tetrafluoroethane, or combinations thereof. Suitable surfactants include sorbitan trioleate and soya lecithin. Oleic acid may also be useful as a surfactant.

Formulations for dispensing from a powder inhaler device will comprise a finely divided dry powder containing the inventive compound and may also include a bulking agent, such as lactose, sorbitol, sucrose, mannitol, trehalose, or xylitol in amounts which facilitate dispersal of the powder from the device, e.g., 50 to 90% by weight of the formulation.

Nasal delivery of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 is also contemplated. Nasal delivery allows the passage of the protein to the blood stream directly after administering the therapeutic product to the nose, without the necessity for deposition of the product in the lung. Formulations for nasal delivery include those with dextran or cyclodextran. Delivery via transport across other mucous membranes is also contemplated.

In practicing the method of treatment or use of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39, a therapeutically effective amount is administered to a subject. As used herein, the term "therapeutically effective amount" means the total amount of each therapeutic composition that is sufficient to show a meaningful patient benefit, i.e., treatment, healing, prevention or amelioration of the relevant medical condition, or an increase in rate of treatment, healing, prevention or amelioration of such conditions. When applied to an individual therapeutic composition, administered alone, the term refers to that

ingredient alone. When applied to a combination, the term refers to combined amounts of the ingredients that result in the therapeutic effect, whether administered in combination, serially or simultaneously. As used herein, the phrase “administering a therapeutically effective amount” of a therapeutic agent means that the patient is treated with said therapeutic composition in an amount and for a time sufficient to induce an improvement, and preferably a sustained improvement, in at least one indicator that reflects the severity of the disorder. An improvement is considered “sustained” if the patient exhibits the improvement on at least two occasions separated by one or more days, or more preferably, by one or more weeks. The degree of improvement is determined based on signs or symptoms, and determinations can also employ questionnaires that are administered to the patient, such as quality-of-life questionnaires. Various indicators that reflect the extent of the patient’s illness can be assessed for determining whether the amount and time of the treatment is sufficient. The baseline value for the chosen indicator or indicators is established by examination of the patient prior to administration of the first dose of the therapeutic agent. Preferably, the baseline examination is done within about 60 days of administering the first dose. If the therapeutic agent is being administered to treat acute symptoms, the first dose is administered as soon as practically possible after the injury has occurred. Improvement is induced by administering therapeutic compositions such as IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 until the patient manifests an improvement over baseline for the chosen indicator or indicators. In treating chronic conditions, this degree of improvement is obtained by repeatedly administering this medicament over a period of at least a month or more, e.g., for one, two, or three months or longer, or indefinitely. A period of one to six weeks, or even a single dose, often is sufficient for treating injuries or other acute conditions. Although the extent of the patient’s illness after treatment may appear improved according to one or more indicators, treatment may be continued indefinitely at the same level or at a reduced dose or frequency. Once treatment has been reduced or discontinued, it later may be resumed at the original level if symptoms should reappear.

One skilled in the pertinent art will recognize that suitable dosages will vary, depending upon such factors as the nature and severity of the disorder to be treated, the patient's body weight, age, general condition, and prior illnesses and/or treatments, and the route of administration. Preliminary doses can be determined according to animal tests, and the scaling of dosages for human administration is performed according to art-accepted practices such as standard dosing trials. For example, the therapeutically effective dose can be estimated initially from cell culture assays. The dosage will depend on the specific activity of the compound and can be readily determined by routine experimentation. A dose can be formulated in animal models to achieve a circulating plasma concentration range that includes the IC<sub>50</sub> (*i.e.*, the concentration of the test compound which achieves a half-maximal inhibition of symptoms) as determined in cell culture, while minimizing toxicities.



Such information can be used to more accurately determine useful doses in humans. Ultimately, the attending physician will decide the amount of polypeptide of the present invention with which to treat each individual patient. Initially, the attending physician will administer low doses of polypeptide of the present invention and observe the patient's response. Larger doses of polypeptide of the present invention can be administered until the optimal therapeutic effect is obtained for the patient, and at that point the dosage is not increased further. It is contemplated that the various therapeutic compositions used to practice the method of the present invention should contain about 0.01 ng to about 100 mg (preferably about 0.1 ng to about 10 mg, more preferably about 0.1 microgram to about 1 mg) of polypeptide of the present invention per kg body weight. In one embodiment of the invention, IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 are administered one time per week to treat the various medical disorders disclosed herein, in another embodiment is administered at least two times per week, and in another embodiment is administered at least three times per week. If injected, the effective amount of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 per adult dose ranges from 1-20 mg/m<sup>2</sup>, and preferably is about 5-12 mg/m<sup>2</sup>. Alternatively, a flat dose can be administered, whose amount may range from 5-100 mg/dose. Exemplary dose ranges for a flat dose to be administered by subcutaneous injection are 5-25 mg/dose, 25-50 mg/dose and 50-100 mg/dose. In one embodiment of the invention, the various indications described below are treated by administering a preparation acceptable for injection containing IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 at 25 mg/dose, or alternatively, containing 50 mg per dose. The 25 mg or 50 mg dose can be administered repeatedly, particularly for chronic conditions. If a route of administration other than injection is used, the dose is appropriately adjusted in accord with standard medical practices. In many instances, an improvement in a patient's condition will be obtained by injecting a dose of about 25 mg of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 one to three times per week over a period of at least three weeks, or a dose of 50 mg of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39 one or two times per week for at least three weeks, though treatment for longer periods may be necessary to induce the desired degree of improvement. For incurable chronic conditions, the regimen can be continued indefinitely, with adjustments being made to dose and frequency if such are deemed necessary by the patient's physician. The foregoing doses are examples for an adult patient who is a person who is 18 years of age or older. For pediatric patients (age 4-17), a suitable regimen involves the subcutaneous injection of 0.4 mg/kg, up to a maximum dose of 25 mg of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist and/or CD39, administered by subcutaneous injection one or more times per week. If an IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonist is in the form of an antibody, a preferred dose range is 0.1 to 20 mg/kg, and more preferably is 1-10 mg/kg. Another embodiment of a dose range is 0.75 to 7.5 mg/kg of

body weight. Humanized antibodies are preferred, that is, antibodies in which only the antigen-binding portion of the antibody molecule is derived from a non-human source. Such antibodies can be injected or administered intravenously.

### 5    **III.    THERAPEUTIC APPLICATIONS**

10    IL-17, IL-18, 4-1BB, CD30 and OX40 antagonists may be used to treat cardiovascular disease. Embodiments of the present invention include methods of treating cardiovascular disease in a subject having having cardiovascular disease comprising administering an effective amount of one or more IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists and/or CD39, alone or in any combination.

Cardiovascular disease includes disease states having pathophysiology of the heart and vasculature systems, as well as organs and systems compromised by disease states of the heart and vasculature systems. Examples include, but are not limited to: inflammation of the heart and/or vasculature such as myocarditis, chronic autoimmune myocarditis, bacterial and viral myocarditis, as well as infective endocarditis; heart failure; congestive heart failure; chronic heart failure; cachexia of heart failure; cardiomyopathy, including non-ischemic (dilated cardiomyopathy; idiopathic dilated cardiomyopathy; cardiogenic shock, heart failure secondary to extracorporeal circulatory support ("post-pump syndrome"), heart failure following ischemia/reperfusion injury, brain death associated heart failure (as described in Owen et al., 1999 (Circulation. 1999 May 18;99(19):2565-70)); hypertrophic cardiomyopathy; restrictive cardiomyopathy; non-ischemic systemic hypertension; valvular disease; arrhythmogenic right ventricular cardiomyopathy) and ischemic (atherogenesis; atherosclerosis; arteriosclerosis; peripheral vascular disease; coronary artery disease; infarctions, including stroke, transient ischemic attacks and myocardial infarctions). Additional disease states encompassed by the definition of cardiovascular disease include: aneurysms; arteritis; angina; embolism; platelet-associated ischemic disorders; ischemia/reperfusion injury; restenosis; mitral and/or tricuspid regurgitation; mitral stenosis; silent myocardial ischemia; Raynaud's phenomena; thrombosis; deep venous thrombosis; pulmonary embolism; thrombotic microangiopathies including thrombotic thrombocytopenic purpura (TTP) and hemolytic uremic syndrome (HUS), essential thrombocythemia, disseminated intravascular coagulation (DIC), and thrombosis and coagulopathies associated with exposure to a foreign or injured tissue surfacethrombophlebitis; vasculitis, including Kawasaki's vasculitis; Takayasu's arteritis; veno-occlusive disease, giant cell arteritis, Wegener's granulomatosis; Schoenlein-Henoch purpura, as well as cardiovascular disease arising from periodontal infections by one or more oral pathogens, such as bacteria.

Additional examples of the therapeutic uses of one or more IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists alone or in combination with CD39 include the treatment of individuals who suffer from coronary artery disease or injury following platelet-associated

ischemic disorders including lung ischemia, coronary ischemia, and cerebral ischemia, and for the prevention of reocclusion following thrombosis, thrombotic disorders including coronary artery thrombosis, cerebral artery thrombosis, intracardiac thrombosis, peripheral artery thrombosis, venous thrombosis, thrombotic microangiopathies including thrombotic thrombocytopenic purpura (TTP) and hemolytic uremic syndrome (HUS), essential thrombocythemia, disseminated intravascular coagulation (DIC), and thrombosis and coagulopathies associated with exposure to a foreign or injured tissue surface, in combination with angioplasty, carotid endarterectomy, anastomosis of vascular grafts, and chronic cardiovascular devices such as in-dwelling catheters or shunts.

Further indications include subjects that are or will be undergoing angioplasty procedures (i.e., balloon angioplasty, laser angioplasty, coronary atherectomy and similar techniques), placement of endovascular prosthetic devices such as carotid, coronary, peripheral arterial or other endovascular stents, dialysis access devices, or procedures to treat peripheral vascular disease; individuals undergoing surgery that has a high risk of thrombus formation (i.e., coronary bypass surgery, insertion of a prosthetic valve or vessel and the like).

In addition, IL-17 and/or IL-18 are prognostic indicators of cardiovascular disease and disease severity. IL-17 and/or IL-18 are also prognostic indicators of donor adequacy and post-transplant outcome. Therefore, further embodiments of the invention include assays for measuring IL-17 and/or IL-18 levels in subjects being screened for cardiovascular disease, cardiovascular disease severity, donor adequacy and post-transplant outcome.

Various indicators that reflect the extent of the patient's illness may be assessed for determining whether the amount and time of the treatment is sufficient. The baseline value for the chosen indicator or indicators is established by examination of the patient prior to administration of the first dose of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists alone or in combination with soluble CD39. Preferably, the baseline examination is done within about 60 days of administering the first dose.

Improvement is induced by repeatedly administering a dose of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists alone or in combination with soluble CD39 until the patient manifests an improvement over baseline for the chosen indicator or indicators. In treating chronic conditions, this degree of improvement is obtained by repeatedly administering this medicament over a period of at least a month or more, e.g., for one, two, or three months or longer, or indefinitely. A period of one to six weeks, or even a single dose, often is sufficient for treating acute conditions.

Although the extent of the patient's illness after treatment may appear improved according to one or more indicators, treatment may be continued indefinitely at the same level or at a reduced dose or frequency. Once treatment has been reduced or discontinued, it later may be resumed at the original level if symptoms should reappear.

Therapeutic compositions of the invention may be administered alone or in combination with a therapeutically effective amount of other drugs. The invention includes the administration of IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists alone or in combination with soluble CD39 concurrently with one or more other drugs that are administered to the same patient in combination with the IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists and/or CD39, each drug being administered according to a regimen suitable for that medicament. "Concurrent administration" encompasses simultaneous or sequential treatment with the components of the combination, as well as regimens in which the drugs are alternated, or wherein one component is administered long-term and the other(s) are administered intermittently. Components can be administered in the same or in separate compositions, and by the same or different routes of administration.

Examples of other drugs or therapeutic compositions that may be used in combination with IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists alone or in combination with soluble CD39 include: analgesic agents, disease-modifying anti-rheumatic drugs (DMARDs), non-steroidal anti-inflammatory drugs (NSAIDs), and any immune and/or inflammatory modulators. Non-steroidal anti-inflammatories may include, but are not limited to: salicylic acid (aspirin); ibuprofen; indomethacin; celecoxib; rofecoxib; ketorolac; nambumetone; piroxicam; naproxen; oxaprozin; sulindac; ketoprofen; diclofenac; other COX-1 and/or COX-2 inhibitors, salicylic acid derivatives, propionic acid derivatives, acetic acid derivatives, fumaric acid derivatives, carboxylic acid derivatives, butyric acid derivatives, oxicams, pyrazoles and pyrazolones, including newly developed anti-inflammatories.

Therapeutic compositions of this invention may be administered with one or more of the following: modulators of other members of the TNF/TNF receptor family, including TNF antagonists, such as etanercept (Enbrel<sup>TM</sup>), sTNF-RI, onercept, D2E7, and Remicade<sup>TM</sup>; IL-1 inhibitors, including IL-1ra molecules such as anakinra and more recently discovered IL-1ra-like molecules such as IL-1Hy1 and IL-1Hy2; IL-1 "trap" molecules as described in U.S. Pat. No. 5,844,099; IL-1 antibodies; solubilized IL-1 receptor, and the like; IL-6 inhibitors (e.g., antibodies to IL-6); IL-8 inhibitors (e.g., antibodies to IL-8); Interleukin-1 converting enzyme (ICE) modulators; insulin-like growth factors (IGF-1, IGF-2) and modulators thereof; transforming growth factor- $\beta$  (TGF- $\beta$ ), TGF- $\beta$  family members, and TGF- $\beta$  modulators; fibroblast growth factors FGF-1 to FGF-10, and FGF modulators; COX-2 inhibitors, such as Celebrex<sup>TM</sup> and Vioxx<sup>TM</sup>; prostaglandin analogs (e.g., E series prostaglandins); matrix metalloproteinase (MMP) modulators; nitric oxide synthase (NOS) modulators, including modulators of inducible NOS; modulators of glucocorticoid receptor; modulators of glutamate receptor; modulators of lipopolysaccharide (LPS) levels; anti-cancer agents, including inhibitors of oncogenes (e.g., fos, jun) and interferons; noradrenaline and modulators and mimetics thereof.

Additional embodiments of compositions that can be administered concurrently with the pharmaceutical compositions of the invention are: cytokines, lymphokines, or other hematopoietic factors such as M-CSF, GM-CSF, Flt3-Ligand, TNF, IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IFN, TNF $\alpha$ , TNF $\beta$ , TNF $\gamma$ , G-CSF, Meg-CSF, thrombopoietin, stem cell factor, and erythropoietin, or inhibitors or antagonists of any of these factors. The pharmaceutical composition can further contain other agents which either enhance the activity of the polypeptide or complement its activity or use in treatment. Such additional factors and/or agents may be included in the pharmaceutical composition to produce a synergistic effect with polypeptide of the invention, or to minimize side effects. Conversely, IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists and/or soluble CD39 may be included in formulations of the particular cytokine, lymphokine, other hematopoietic factor, thrombolytic or anti-thrombotic factor, or anti-inflammatory agent to minimize side effects of the cytokine, lymphokine, other hematopoietic factor, thrombolytic or anti-thrombotic factor, or anti-inflammatory agent.

Further embodiments of drugs to be administered concurrently include but are not limited to antivirals, antibiotics, analgesics, corticosteroids, antagonists of inflammatory cytokines, non-steroidal anti-inflammatories, pentoxifylline, thalidomide, and disease-modifying antirheumatic drugs (DMARDs) such as azathioprine, cyclophosphamide, cyclosporine, hydroxychloroquine sulfate, methotrexate, leflunomide, minocycline, penicillamine, sulfasalazine and gold compounds such as oral gold, gold sodium thiomalate, and aurothioglucose.

Of course, IL-17, IL-18, 4-1BB, CD30 and/or OX40 antagonists and/or soluble CD39, as well as other therapeutic compositions described above, may be administered in conjunction with other recognized therapies or treatments, such as any surgical procedures involving the heart and vasculature (coronary bypass, heart transplant, valve replacement, angioplasty, stenting, atherectomy, aortic aneurysm repair, valve plication, ventricular assist device insertion, ventricular volume reduction surgery, any form of peripheral arterial surgery including bypass, vessel recanalisation or reconstruction, pediatric cardiovascular surgery including repair and correction of complex congenital lesions); Lipid-lowering drugs (such as, but not limited to Lipitor, simvastatin, pravastatin, atorvastatin, non-HMG CoA reductase inhibitors); blood pressure-regulating drugs (including but not limited to calcium channel antagonists, ACE-inhibitors, beta-blockers, orally and systemically available nitric oxide donors such as GTN); angiotensin-converting enzyme inhibitors, and peroxisome proliferator-activated receptor ligands.

In other embodiments of the invention, 4-1BB, CD30 and/or OX40 antagonists may be used to prevent, reduce and/or ameliorate the cardiotoxicity of chemotherapeutics. Drug toxicity remains a significant barrier to the delivery of curative doses of cancer chemotherapy. Many chemotherapeutic drugs cause direct injury to the heart, either acutely

in the form of myocardial tissue injury or dysrhythmias, or in a chronic fashion associated with congestive heart failure. Examples of acute cardiotoxicity include supraventricular tachyarrhythmias, which may be associated ECG changes, such as ST-T segment changes, decreased voltage, T-wave flattening, as well as atrial and ventricular ectopy. Acute effects occur in up to 40% of patients receiving bolus doxorubicin and are usually transient. Chronic anthracycline cardiotoxicity may be manifested as arrhythmias, myocarditis, pericarditis, myocardial infarction and cardiomyopathy that is dose- and schedule-dependent. Above cumulative bolus doses of 550 mg/m<sup>2</sup> the risk of congestive heart failure increases rapidly. Doses of less than 450 mg/m<sup>2</sup> pose a risk of less than 10%. Patients receiving anthracyclines also demonstrate late-appearing cardiac toxicity occurring greater than 5 years after exposure to doxorubicin. Cardiac dysfunction is manifested as congestive heart failure or dysrhythmias and can occur in patients that were previously asymptomatic. It is estimated that approximately 5% of patients surviving ten years after exposure to doxorubicin will experience this toxicity (see, Page, R., *Cancer Management: A Multidisciplinary Approach*, PRR Inc., Fifth Edition (2001)).

Principal among the cardiotoxic agents are cytostatic antibiotics of the anthracycline class. The class of anthracyclines includes, but is not limited to, Adriamycin (Doxorubicin), Daunorubicin, Ellence (Epirubicin), Idarubicin, Mitroxantrone, and the like. Therefore, embodiments of the invention provide methods of preventing, reducing and/or ameliorating the cardiotoxic effects of anthracyclines comprising administering an effective amount of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention also provide compositions for preventing, reducing and/or ameliorating the cardiotoxic effects of anthracyclines comprising an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists.

Embodiments of the invention provide methods of preventing, reducing and/or ameliorating the cardiotoxic effects of anthracyclines selected from the group consisting of Adriamycin (Doxorubicin), Daunorubicin, Ellence (Epirubicin), Idarubicin and Mitroxantrone, comprising administering an effective amount of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention also provide compositions for preventing, reducing and/or ameliorating the cardiotoxic effects of anthracyclines selected from the group consisting of Adriamycin (Doxorubicin), Daunorubicin, Ellence (Epirubicin), Idarubicin and Mitroxantrone, comprising an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists.

4-1BB antagonists, CD30 antagonists and/or OX40 antagonists may be used to prevent, reduce and/or ameliorate the cardiotoxic effects of other chemotherapeutics having cardiotoxicity, such as, but not limited to: Amsacrine, Busulfan, Cisplatin, Cyclophosphamide, Fluorouracil, Herceptin (and other Her2/neu-targeted modalities),

Ifosfamide, Interferons, Interleukin-2, Mitomycin, Paclitaxel, Vinblastine, Vincristine and Xeloda (capecitabine).

Therefore, embodiments of the invention provide methods of preventing, reducing and/or ameliorating the cardiotoxic effects of chemotherapeutics having cardiotoxic side effects, comprising administering an effective amount of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention also provide compositions for preventing, reducing and/or ameliorating the cardiotoxic effects of chemotherapeutics having cardiotoxic side effects comprising an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists.

Embodiments of the invention provide methods of preventing, reducing and/or ameliorating the cardiotoxic effects of chemotherapeutics selected from the group consisting of Amsacrine, Busulfan, Cisplatin, Cyclophosphamide, Fluorouracil, Herceptin (and other Her2/neu-targeted modalities), Ifosfamide, Interferons, Interleukin-2, Mitomycin, Paclitaxel, Vinblastine, Vincristine and Xeloda (capecitabine), comprising administering an effective amount of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention also provide compositions for preventing, reducing and/or ameliorating the cardiotoxic effects of chemotherapeutics selected from the group consisting of Amsacrine, Busulfan, Cisplatin, Cyclophosphamide, Fluorouracil, Herceptin (and other Her2/neu-targeted modalities), Ifosfamide, Interferons, Interleukin-2, Mitomycin, Paclitaxel, Vinblastine, Vincristine and Xeloda (capecitabine), comprising an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists.

Embodiments of the invention provide methods of treating cancer in a subject in need thereof, wherein the dosage of a chemotherapeutic having cardiotoxicity is increased to more effectively treat the cancer but the cardiotoxic effects of the chemotherapeutic is prevented, reduced and/or ameliorated by administering an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention provide methods of treating cancer in a subject in need thereof, wherein the dosage of an anthracycline is increased to more effectively treat the cancer but the cardiotoxic effects of the anthracycline is prevented, reduced and/or ameliorated by administering an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention provide methods of treating cancer in a subject in need thereof, wherein the dosage of an anthracycline selected from the group consisting of Adriamycin (Doxorubicin), Daunorubicin, Ellence (Epirubicin), Idarubicin and Mitroxantrone is increased to more effectively treat the cancer but the cardiotoxic effects of the anthracycline is prevented, reduced and/or ameliorated by administering an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists. Embodiments of the invention provide methods of treating cancer in a subject in need thereof, wherein the dosage of a chemotherapeutic selected from the group consisting of

Amsacrine, Busulfan, Cisplatin, Cyclophosphamide, Fluorouracil, Herceptin (and other Her2/neu-targeted modalities), Ifosfamide, Interferons, Interleukin-2, Mitomycin, Paclitaxel, Vinblastine, Vincristine and Xeloda (capecitabine) is increased to more effectively treat the cancer but the cardiotoxic effects of the chemotherapeutic is prevented, reduced and/or ameliorated by administering an antagonist selected from the group consisting of a 4-1BB antagonists, CD30 antagonists and/or OX40 antagonists.

The present invention is not to be limited in scope by the specific embodiments described herein, which are intended as single illustrations of individual aspects of the invention, and functionally equivalent methods and components are within the scope of the invention. Indeed, various modifications of the invention, in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

The invention having been described, the following examples are offered by way of illustration, and not limitation.

#### Sequence Identity Numbers and Associated Molecules

SEQ ID NO.	Molecule
1	IL-17 polynucleotide sequence
2	IL-17 amino acid sequence
3	IL-17 Receptor polynucleotide sequence
4	IL-17 Receptor amino acid sequence
5	IL-18 Receptor: IL-1Rrp1 polynucleotide sequence
6	IL-18 Receptor: IL-1Rrp1 amino acid sequence
7	IL-18 Receptor: AcPL polynucleotide sequence
8	IL-18 Receptor: AcPL amino acid sequence
9	IL-18 Binding Protein a polynucleotide sequence
10	IL-18 Binding Protein a amino acid sequence
11	IL-18 Binding Protein-Fc fusion amino acid sequence
12	IL-18 polynucleotide sequence (unprocessed)
13	IL-18 amino acid sequence (unprocessed)
14	IL-18 amino acid sequence (ICE-processed)
15	4-1BB-L polynucleotide sequence
16	4-1BB-L amino acid sequence
17	4-1BB polynucleotide sequence
18	4-1BB amino acid sequence
19	CD30-L polynucleotide sequence (nt 1-648)



20	CD30-L polypeptide sequence (aa 1-215)
21	CD30-L polynucleotide sequence (nt 1-705)
22	CD30-L polypeptide sequence (aa 1-234)
23	CD30 polynucleotide sequence
24	CD30 polypeptide sequence
25	OX40-L polynucleotide sequence
26	OX40-L polypeptide sequence
27	OX40 polynucleotide sequence
28	OX40 polypeptide sequence
29	CD39 polynucleotide sequence
30	CD39 polypeptide sequence
31	Flag® octapeptide
32	Linker - (Gly) <sub>4</sub> Ser(Gly) <sub>5</sub> Ser
33	Linker - GlyAlaGlyGlyAlaGlySer(Gly) <sub>5</sub> Ser
34	Linker - (Gly <sub>4</sub> Ser) <sub>2</sub>
35	Linker - (GlyThrPro) <sub>3</sub>
36	Linker - (Gly <sub>4</sub> Ser) <sub>3</sub> Gly <sub>4</sub> SerGly <sub>5</sub> Ser

## EXAMPLES

5

### EXAMPLE 1

#### IL-17 AND IL-18 PLASMA LEVELS ARE ELEVATED IN CARDIOMYOPATHY PATIENTS

These studies demonstrate IL-17 and IL-18 are elevated in human patients having various forms and severity of cardiovascular disease.

In a series of studies, plasma levels of IL-17 and IL-18 were found to be elevated in patients having acute and chronic heart failure. Plasma from brain-dead organ donors was obtained at the time of heart removal and stored. The clinical outcome of the recipient that received the various organs was noted. A group of recipients that survived and did well was collected along with a group that died within 72 hours of transplantation due to cardiac failure refractory to maximal medical support. The plasma from the original donors, recipients and unused donors having an ejection fraction (EF) of less than 30% was assayed for IL-17 and IL-18. Cytokine levels were measured in plasma samples essentially as described in the protocols provided in commercially available ELISA kits (see, for example, QUANTKINE® R&D Systems, Minneapolis, MN, which provides assays for the quantitative determination of human IL-17 and human IL-18).

As shown in Figures 1A and 1B, IL-17 and IL-18 were elevated in patients that died shortly after transplantation in contrast to patients that survived. IL-17 and IL-18 were also

elevated in unused donors having an ejection fraction (EF) of less than 30%, suggesting a correlation between circulating IL-17 and IL-18 levels and disease severity. This study further shows the diagnostic and prognostic value of assaying for IL-17 and IL-18 cytokine levels in heart patients, such as for the assessment of post-transplant survival.

Using the samples described above, IL-18 receptor expression was assessed. Heart samples were homogenized in ice-cold lysis buffer (New England Biolabs, Beverly, MA). The homogenate was centrifuged at 4°C (12000 x 5 mins) and the supernatant assayed for protein content (Pierce BCA kit). The same total amount of protein (20mg/lane) was subjected to SDS-PAGE using 5% gels. Proteins were then transferred to nitrocellulose membrane and IL-18 receptor visualized using a polyclonal antibody raised against IL-18R alpha (AF840- R&D Systems, Minneapolis, MN), and the ECL kit.

As shown in Figure 2 the relative abundance of IL-18 receptor is higher in patients having an ejection fraction (EF) of less than 30% as compared to patients in end stage heart failure- ESF (i.e., NYHA stage 4 cardiomyopathy) and patients having an ejection fraction of greater than 60%. These data demonstrate that elevated IL-18 receptor expression is associated with impaired myocardial function. Given that IL-18 signals through the Toll-IL-1 receptor pathway (TIR) and that both lipopolysaccharide and IL-1 are negatively inotropic, elevated expression of the IL-18 receptor could well account for part of the myocardial dysfunction seen in these patients.

Samples from cardiac patients participating in the multi-center Renaissance Trial were evaluated. The patients exhibited a continuum of functional capacity and objective evidence of cardiovascular disease, as classified by the Criteria Committee of the New York Heart Association (*Nomenclature and Criteria for Diagnosis of Diseases of the Heart and Great Vessels*. 9<sup>th</sup> ed. Boston Mass: Little, Brown & co; 1994:253-256). Samples were evaluated for cytokine levels using the assays described above.

Figures 3A-3D depict the plasma concentration of IL-17 and IL-18 (pg/ml) in cardiomyopathy patients diagnosed in NYHA classes 1, 2, 3a, 3b and 4. This data shows a dramatic and unexpected increase in the amount of circulating IL-17 in NYHA classes 2, 3a and 3b (Figure 1A). Elevated IL-17 levels were found in both non-ischemic and ischemic cardiomyopathy for the same classes (Figure 1B). IL-17 levels were significantly higher in NYHA class 3a for ischemic cardiomyopathy. Significantly, this data shows a direct correlation between IL-17 levels and progression of disease up to NYHA class 3b and a decrease in IL-17 in NYHA class 4.

Plasma levels of IL-18 were also elevated in NYHA classes 2, 3a, 3b and 4 (Figure 3C). Similar to IL-17, this data shows a direct correlation between IL-18 levels and progression of disease up to NYHA class 3b with a decrease in IL-18 in NYHA class 4 (Figure 3C). When broken down into non-ischemic and ischemic cardiomyopathy, IL-18 levels were elevated in both non-ischemic and ischemic cardiomyopathy for the same NYHA

classes (Figure 3D). Non-ischemic cardiomyopathy patients had comparatively higher levels of IL-18 for NYHA classes 2, 3a and 3b.

This data demonstrates that IL-17 plasma levels can be used as a prognostic indicator of cardiovascular disease and disease severity. Without being bound by theory, the relative expression of IL-17 and IL-18 may be diagnostic of non-ischemic versus ischemic cardiomyopathy (compare Figures 3B and 3D). Therefore, assays to detect circulating levels of IL-17 and IL-18 may be used to diagnose cardiovascular disease and qualitatively assess disease severity. Taken together, this data shows IL-17 and IL-18 are implicated in cardiovascular disease and provides a basis for treating cardiovascular disease by administering IL-17 and/or IL-18 antagonists, alone or in combination.

## EXAMPLE 2

### CYTOKINE PROFILES OF HEART TRANSPLANT RECIPIENTS

This study shows, *inter alia*, that IL-17, IL-18 and soluble 4-1BB are elevated in heart transplant recipients that died within 72 hours of transplantation. This data shows that myocardial dysfunction is associated with significantly elevated levels of IL-17, IL-18 and soluble 4-1BB.

Cardiac transplantation remains a major therapeutic modality for patients with end-stage heart failure; however, the number of donor organs significantly limits its availability. This situation is worsened by the fact that around 20% of organ donors have such severe acute myocardial dysfunction associated with brain death that their hearts are unable to be used for transplantation (Hosenpud JD, *et al.*, *Heart Lung Transplant.* 2001, 20(8):805-15). Brain death is a catastrophic event associated with marked activation of the immune system and elevated plasma levels of cytokines such as TNF $\alpha$  and IL6 (Takada, M, *et al.*, *Transplantation* 1998, 65(12):1533-42 and Birks, EJ, *et al.*, *Transplant Proc.* 2001;33(5):2749-51). Cytokines are critical regulators of the T-helper 1 (Th1) and Th2 T-cell responses (Neurath, MF, *et al.*, *Nat Med.* 2002, 8(6):567-73). The Th1 response results in pro-inflammatory cytokine release characterized by macrophage activation and, if unopposed, may result in tissue damage. The Th2 response results in a humoral immune response that in general opposes the Th1 response.

We hypothesized that death early after heart transplantation could be due to donor derived factors impacting on heart function either directly or indirectly, for example by initiating an acute rejection episode, ultimately resulting in myocardial dysfunction. To test this hypothesis we obtained plasma from two groups of heart transplant donors (as described above). Group A comprised samples from 16 organ donors where the recipient had an uneventful postoperative course and survived greater than 1 year. Group B samples were obtained from 14 donors where the recipients died within 72 hours of transplantation with myocardial dysfunction refractory to maximal medical therapy. The circulating levels of the

Th1 (pro-inflammatory) cytokines interferon gamma (IFN $\gamma$ ), IL-12, IL-15, IL-17 and IL-18 along with the Th2 (anti-inflammatory) cytokines IL-4, IL-5, IL-10 and IL-13 were measured. Cytokine levels were determined using LUNIMEX<sup>®</sup> technology (Upstate, Waltham, MA), QUANTIKINE<sup>®</sup> ELISA kits (R&D Systems) or a custom made ELISA for soluble 4-1BB (using capture and detection antibodies, also from R&D systems). The control group consisted of 21 healthy patients with echocardiographically normal myocardial function undergoing routine coronary artery bypass graft surgery. The circulating Th2/Th1 ratio was obtained by dividing the sum of the Th2 cytokines by the sum of Th1 cytokines, both in pg/ml. In addition, as a potential marker of T-cell interaction with antigen presenting cells, we also measured the level of the soluble receptor 4-1BB. 4-1BB is present on activated T-cells and 4-1BB ligand (4-1BB-L) is present on antigen presenting cells; engagement of 4-1BB by 4-1BB-L acts as a co-stimulatory signal (Kwon, B., *et al.*, *Mol Cells*. 2000;10(2):119-26). Inflammatory mediator levels in groups A and B were compared to those in 21 non-brain dead control subjects.

Figure 9 shows that 4-1BB levels were significantly elevated in the patients with heart failure compared to normal subjects suggesting activation of this system in human heart failure, in common with rheumatoid arthritis patients (Eur J Immunol. 1998 Jan;28(1):290-5).

As shown in the Table 2, plasma samples from brain dead organ donors, where the recipients had an uneventful outcome post-transplantation (group A), contained significantly elevated levels of the Th2 cytokines IL-4, 10 and 13, along with the Th1 cytokines IFN $\gamma$ , IL-12, 17 and 18 compared to control subjects. Overall, however, this maintained a circulating Th2/Th1 ratio of 0.32, which was not significantly different from 0.45 seen in control subjects. In group B, where the recipients died within 72 hours of transplantation, the Th2 cytokines IL-4 and 13 were unchanged from control levels, IL-10 was elevated compared to control subjects, but significantly reduced compared to Group A samples. IFN $\gamma$  was elevated compared to control samples and IL-12 was unaltered. However, marked elevations in the levels of IL-17 and IL-18 were identified, resulting in a reduction in the Th2/Th1 ratio to 0.028 ( $P < 0.05$ ). Whilst soluble 4-1BB levels were similar in control and group A patients, significantly elevated levels were found in the plasma of group B patients (see Figure 4).

These data identify a change in the circulating cytokine balance towards a pro-inflammatory (Th1) environment in the plasma of donors associated with early recipient death post-transplantation. Elevations in the levels of IL-17 and IL-18 are predominantly responsible for this. IL-18 utilizes the same signaling pathway as IL-1 and lipopolysaccharide (Sims, JE, *Curr Opin Immunol*. 2002;14(1):117-22), both of which are negatively inotropic. IL-17 induces nitric oxide production from a variety of cells, and also stimulates production of a number of cytokines and prostaglandins from a variety of cell types. The elevated levels of IL-17 and IL-18 seen, in particular, in group B patients could well contribute to the adverse recipient outcome early after transplantation. Significantly elevated levels of soluble

4-1BB were also observed in the plasma samples of donors in group B, suggesting that enhanced antigen presenting cell:T-cell interaction may occur in these patients.

Analysis of donor cytokine expression and levels of molecules such as IL-17, IL-18 and 4-1BB is valuable in identifying hearts from donors that may require intensive supportive therapy post-transplantation, or indeed that should not be used for transplantation. These data emphasize the importance of immune activation in brain death, its potential impact on outcome post-transplantation and the idea that therapies aimed at altering the donor cytokine balance may result in improved recipient outcome. These results suggest that elevated 4-1BB, as well as other cytokines such as IL-17 and IL-18, primes the heart for rejection in a recipient soon after transplantation or that these 4-1BB, IL-17 and/or IL-18 may directly mediate impaired myocardial performance. Thus, the studies presented herein demonstrate that IL-17, IL-18 and 4-1BB are implicated in cardiovascular disease and provides a basis for treating cardiovascular disease by administering IL-17, IL-18 and/or 4-1BB antagonists, alone or in combination.

Table 2.

	IL-4	IL-5	IL-10	IL-13	IFN $\gamma$	IL-12	IL-15	IL-17	IL-18	4-1BB
Control mean (SE)	2.6 (0.9)	0.9 (0.3)	1.7 (0.3)	1.9 (0.7)	1.9 (0.4)	10.4 (4.7)	38.7 (13.85)	1.1 (0.5)	68.1 (23)	30 (20)
Group A mean (SE)	14 (5.3)	2.4 (1.6)	19.9 (4.8)	8.8 (5.9)	20.7 (8.6)	41.5 (31.6)	8.6 (3.1)	18 (18)	186 (50)	90 (80)
Group B mean (SE)	3.5 (0.4)	0.45 (0.1)	7 (2)	1.1 (0.2)	8.4 (1.5)	7.4 (1.9)	5.4 (1.8)	292 (70)	373 (51)	420 (170)

### EXAMPLE 3 IL-17 LEVELS AND HEART CHAMBER DIMENSIONS

These studies demonstrate that exposure to IL-17 results in a drop in left ventricle dimensions.

Female C57/Black6 mice were anesthetised with avertin. A midline laparotomy was performed and the inferior vena cava was cannulated. A base line echocardiogram was then performed. Human IL-17 (200ng) was then administered in a bolus of 200ml of PBS (pH 7.4). At the indicated time points the echocardiogram was repeated and left ventricular internal diameter in diastole and systole were determined.

As shown in Figure 4, these data demonstrate that IL-17, following acute administration, results in diminished chamber dimensions with maintained ejection fraction. The reduction in diastolic dimensions may suggest that IL-17 plays some part in mediating

diastolic dysfunction, though it may also be involved in systolic heart failure. This data suggests IL-17 is implicated in cardiovascular disease and provides a basis for treating cardiovascular disease by administering IL-17 antagonists.

5

## EXAMPLE 4

## IL-17 AND IL-18 LEVELS ARE ELEVATED IN A MURINE MYOSIN-INDUCED MYOCARDITIS MODEL

This study shows that IL-17 and IL-18 are elevated in an experimental autoimmune myocarditis (EAM) model, which shows a similar course of disease as seen in humans. The terms “EAM” and “cardiac myosin-induced myocarditis” are used interchangeably to describe similar models.

It is well known in the art that myocarditis is associated with an autoimmune process in which cardiac myosin is a major autoantigen. Cardiac myosin-induced myocarditis histologically resembles viral-induced myocarditis. It is generally agreed that both antibody and T-cells are implicated in inflammatory heart disease, such as myocarditis. Experimental autoimmune myocarditis models that mimic the disease in humans have been developed in a variety of rodent models and are well known in the art (see, for example, in A/J mice: Neu, N, *et al.*, *J. Immunol.* 1987, 139:3630-3636 and Smith, SC, *et al.*, *J. Immunol.* 1991, 147:2141-2147; in BALB/c mice: Pummerer, CL, *et al.*, *J. Clin. Invest.* 1996, 97:2057-2062 and Liao, L, *et al.*, *J. Clin. Invest.* 1993, 92:2877-2882; and in Lewis rats: Kodama, M, *et al.*, *Clin. Immunol Immunopath.* 1991, 57:250-262 and Wegmann, KW, *et al.*, *J. Immunol.* 1994, 153:892-900).

It has been shown in the A/J mouse EAM model that blocking IL-4 with anti-IL-4 monoclonal antibody reduced the severity of EAM by shifting the immune response from a Th2-like response to a Th1-like response with a concomitant increase in INF- $\gamma$  production, which suggested INF- $\gamma$  limits the disease. Blockade of INF- $\gamma$  was shown to exacerbate disease, thereby establishing the basis for using an INF- $\gamma$  knockout (INF- $\gamma^{-/-}$ ) in a EAM model (Afanasyeva, M, *et al.*, *Am J Pathol* 2001, 159:193-203).

Autoimmune myocarditis was induced in mice by immunizing BALB/c and INF- $\gamma^{-/-}$  knockout mice with 200 ug  $\alpha$ -myosin heavy chain plus MTB (mycobacterium tuberculosis was included at 5mg/ml H37Ra; Difco/Bectin Dickinson, Franklin Lakes, NJ) and Pertussis toxin at 500 ng (List biological laboratories, Campbell, CA) intraperitoneally in a volume of 400 ul. Interferon gamma-deficient mice were obtained from Jackson Laboratories, Bar Harbor, ME. BALB/c and INF- $\gamma^{-/-}$  were boosted on Day 7 by immunization with myosin formulated in Complete Freund's Adjuvant (CFA) with omission of Pertussis toxin. Animals were sacrificed at days 35, 55 or 85 and the following analysis were preformed: histology, anti-myosin antibody titre, serum cytokine profile and antigen specific T-cell proliferation assays. Some animals underwent echocardiography.

BALB/c and  $\text{INF-}\gamma^{-/-}$  mice that were immunized with  $\alpha$ -myosin heavy chain developed antibodies against myosin peptide as measured by standard ELISA techniques. Myosin-immunized BALB/c and  $\text{INF-}\gamma^{-/-}$  mice developed myocardial lesions, with the knockout mice showing an increase in lesion number and severity over negative controls and BALB/c mice. In addition,  $\text{INF-}\gamma$  knockout mice showed a greater degree of myocardial inflammation and fibrosis, as well as a greater percent increase in heart/body weight ratio over negative controls and BALB/c mice. Myosin-specific T-cell proliferation responses were shown in myosin-immunized  $\text{INF-}\gamma$  knockout and BALB/c mice, as measured by standard thymidine incorporation assays.

Furthermore, plasma levels of IL-17 and IL-18 were elevated in the cardiac myosin-induced myocarditis model. IL-17 and IL-18 were assayed using commercially available ELISA kits, such as described in Example 1. As shown in Figure 5A, IL-17 levels were markedly increased in  $\text{INF-}\gamma^{-/-}$  mice at day 28 and 35 post immunization. Plasma levels of IL-18 rose sharply at 9 days post immunization and remained elevated out to day 28 (Figure 5B). This data clearly shows that circulating plasma levels of IL-17 and IL-18 are elevated in the myosin-induced model and that IL-17 and IL-18 are associated with myocarditis immunopathology. This data provides a basis for treating cardiovascular disease by administering IL-17 and/or IL-18 antagonists, alone or in combination.

## EXAMPLE 5

### IL-17 EXPRESSION IN T-CELLS IN THE MYOSIN-INDUCED MYOCARDITIS MODEL

These experiments demonstrate that IL-17 is expressed at high levels in T-cell populations isolated from EAM mice. Details of the EAM model are provided in the previous Example.

T-cells were isolated from EAM mice using standard techniques and stimulated with anti-CD3 antibody. As shown in Figure 6A, the animal immunized with cardiac myosin having histologically demonstrated cardiopathology (animal B) had significantly higher expression levels of IL-17 over negative controls (animals C and D), as well as an animal immunized with cardiac myosin, but not exhibiting signs of cardiopathology (animal A).

IL-17 expression in EAM mice was shown to be a myosin-specific T-cell response. On average, IL-17 levels were approximately 25 fold higher in T-cells isolated from animals immunized with cardiac myosin and exposed to antigen presenting cells fed myosin over antigen presenting cells not exposed to myosin (Figure 6B).

In a related study, the antigen presenting cells were exposed to  $\alpha$ -myosin peptide rather than being fed whole  $\alpha$ -myosin protein. As in the previous study, T-cells from the animal immunized with cardiac myosin and having histological evidence of cardiopathology (animal B) released surprisingly high levels of IL-17 in response to antigen-specific

stimulation by peptide-pulsed antigen presenting cells (Figure 6C). Without being bound by theory, this study suggests that activated (likely CD4+) T-cells when encountering antigen presenting cells bearing heart antigens proliferate and release IL-17. The released IL-17 may contribute to inflammatory cell infiltration into the heart, direct myocardial damage or may also have a direct depressant effect on heart function.

#### EXAMPLE 6 IL-18 AND IL-18 BINDING PROTEIN PLASMA LEVELS IN ACUTE CORONARY SYNDROME PATIENTS

These studies show that IL-18 is elevated in patients having acute coronary syndrome and that IL-18 correlates with increased risk for major adverse cardiac events (MACEs).

Patients were stratified into three patient groups: those having stable coronary artery disease (CAD), acute coronary syndrome (ACS) with cardiac troponin I (cTnI) plasma levels less than 0.4 ng/ml or acute coronary syndrome (ACS) with cardiac troponin I (cTnI) plasma levels greater than 0.4 ng/ml. The CAD group included patients having stable angina and the ACS group included patients having unstable angina, non-ST elevation myocardial infarction, ST elevation myocardial infarction and sudden ischemic death.

Cardiac troponin I is recognized as a reliable biochemical marker for the diagnosis of myocardial injury, such as myocardial necrosis resulting from ischemia. Elevated cardiac troponin I is strongly associated with a high-risk profile for short and long term adverse cardiac events. Measuring the relative levels of cardiac troponin I provides a reliable stratification of risk and prediction of outcome for acute coronary syndrome patients. In this study, patients having a cardiac troponin I level of greater than 0.4 ng/ml suffered a serious adverse cardiac event, often resulting in death, within ten days.

Cytokine levels were measured in plasma samples from patients from each of the three groups essentially as described in the protocols provided in commercially available ELISA kits (see, for example, QUANTKINE® R&D Systems, Minneapolis, MN, which provides assays for the quantitative determination of human IL-18). IL-18 Binding Protein A (IL-18Bpa) was measured using commercially available antibodies from R&D. Plates were coated with a capture antibody. Samples were then added to wells and incubated at room temperature for 2 hours. Wells were then washed, incubated with a biotinylated detection antibody and the immunoreaction detected using standard techniques and TMB as chromogen. IL-18 Binding Protein produced in house was used as standard.

As shown in Figure 8A, plasma levels of IL-18 was elevated in the ACS group having a cTnI level of less than 0.4 ng/ml, and more significantly, IL-18 levels were even higher in patients in the ACS group having a cTnI level of greater than 0.4 ng/ml. Figure 8B shows the ratio of IL-18:IL-18 BPa among the three groups and illustrates that IL-18 Binding Protein



levels are not elevated in either the ACS groups, which demonstrates that the elevated IL-18 levels are unopposed by this immune mechanism.

This data shows that circulating levels of IL-18 are elevated in ACS patients at high risk of subsequent major adverse cardiac events and that IL-18 Binding Protein levels do not rise concomitantly to counteract the immune response. Thus, IL-18 is implicated in cardiovascular disease and provides a basis for treating cardiovascular disease by administering IL-18 antagonists, alone or in combination with other antagonists described herein.

In addition, elevated IL-18 levels correlate with elevated cTnI levels and disease progression or disease severity. Therefore, IL-18 may also serve as a surrogate marker for increased risk for serious adverse cardiac events. Embodiments of the present invention include diagnostic assays for determining the level of IL-18 in patients having cardiovascular disease for the purpose of assessing disease progression or severity.

#### EXAMPLE 7

##### 4-1BB LIGAND KNOCKOUT MICE ARE PROTECTED IN AN ADRIAMYCIN<sup>®</sup>-INDUCED MURINE MODEL OF DILATED CARDIOMYOPATHY

These experiments demonstrate that 4-1BB-L knockout mice (4-1BB-L<sup>-/-</sup> or 4-1BB-L KO) showed no mortality and had a delayed onset of cardiac dysfunction in an Adriamycin<sup>®</sup>-induced murine model of dilated cardiomyopathy.

Adriamycin<sup>®</sup> (Doxorubicin Hydrochloride, an anthracycline antibiotic- Pharmacia, Milan, Italy) has been shown to exhibit myocardial toxicity resulting in congestive heart failure, i.e., ischemic or dilated cardiomyopathy. Many animal models have been developed over the years using using Adriamycin<sup>®</sup> and are well-known in the art.

Male 4-1BB-L<sup>-/-</sup> (53 days old) and C57Bl/6 (59 days old, Taconic, Germantown, NY) were used in the study. Mice were anesthetized with 100-150ul ketamine-xylazine, weighed and ear tagged. Baseline echocardiographic (echo) measurements were taken from the parasternal long axis view while the mouse lay prone on a 1cm thick agarose gel pad (Sonos5500 - Philips Co., with a S12 probe and a Instec heated microscope stage with 1cm thick 1% agarose gelpad). Measurements taken included: AoR diameter, LA dimension, ACS, RVd, IVSd, LVIDd, LVPWd, IVSs, LVIDs, LVPWs, and HR. Echo evaluations were performed at weeks 0, 2.5, 5 and 7 and a phenotype assigned to each mouse based on the weekly echo measurements. Fractional shortening (FS) was calculated by the echo instrument. Measurements were normalized between mice by obtaining a PSLA image where the AoR and LA dimensions had a 1:1 ratio. Additionally, LV dimensions were taken from a Mmode image obtained by dissecting the LV perpendicularly through the PW, just distal to the tips of the mitral valve leaflets (sweep speed 100). Diastolic measurements were taken at the peak of the QRS complex of the EKG, while systolic measurements were

recorded at the point of maximal contraction of the PW. All measurements were recorded onto optical disk, videotaped and printed.

After all echo measurements were obtained, the mice were injected retroorbitally with 22.5 mg/kg Adriamycin® (Sigma-Aldrich/Fluka, St. Louis, MO) and allowed to recover from anesthesia. Adriamycin was prepared from a powdered stock by dissolving 10mg in 1ml sterile water for a stock concentration of 10mg/ml. Further dilutions were made with sterile saline. Solutions were made on the day of injection. The mice that received a dose of 22.5 mg/kg were injected with 150 ul of a 3.75 mg/ml working dilution for a total dose of 0.5625 mg. Body weights were recorded daily.

If an animal was sacrificed due to a greater than 15% loss in body weight or at the end of the study, the hearts were harvested and fixed in 10% NBF (neutral buffered formalin). Briefly, thoracic incisions were made to expose the heart. Using a 27g needle, 1M KCl (final concentration=50mM) was injected directly into the heart to stop the hearts in diastole; PBS was then injected directly into the heart to flush blood out of the chambers. The heart was carefully removed, rinsed in PBS and placed into 10% NBF.

As mentioned above, a phenotype was assigned to each mouse based on the echo results and each mouse was classified according to the degree of cardiotoxicity into stages I, II, III or IV. The following criteria was used to phenotype the mice: Diastolic Dysfunction: LVIDd % Δ and LVIDs % Δ reduced >10% and FS same or increased; Systolic Dysfunction: LVIDd % Δ plus LVIDs % Δ increased >25% and FS reduced >12%; Diastolic and Systolic Dysfunction: LVIDd % Δ plus LVIDs % Δ reduced >20% and FS reduced >12%; Dilated: LVIDd % Δ > 12% and LVIDs % Δ > 12%.

4 of 10 wild type mice died between 8 and 10 days after Adriamycin® injection. These deaths are considered chronic heart failure deaths. Wild-type mice challenged with Adriamycin® had an approximate 2-week mortality rate of 50% and approximately 66% of the mice exhibited evidence of cardiac dysfunction 2 to 2.5 weeks post Adriamycin®-challenge. The wild-type survivors generally showed two phenotypes: (a) systolic dysfunction with LV chamber dilation with diminished ejection fraction (EF), and (b) diastolic dysfunction with progressive reduction in chamber dimensions with diminished ventricular filling but maintained EF.

In contrast, no mortality was observed in the 4-1BB-L KO mice and none of the 4-1BB-L KO mice showed signs of the most severe cardiotoxicity following Adriamycin® challenge compared to 59 to 71% of wild type mice.

Table 3.

	4-1BB-L KO	Wild Type Bl6	Historical Bl6 cntls
No Dysfunction	7/14 (50%)	2/7 (29%)	9/22 (41%)

(Class I)			
Transient Dysfunction (Class II)	1/14 (7%)	0/7 (0%)	1/22 (5%)
Progressive Dysfunction (Class III)	6/14 (43%)	1/7 (14%)	5/22 (23%)
Chronic Failure (Class IV)	0/14 (0%)	4/7 (57%)	7/22 (32%)
Total cardiotoxicity	7/14 (50%)	5/7 (71%)	13/22 (59%)

These results demonstrate that the 4-1BB and 4-1BB-L receptor:ligand pair are implicated in immune responses associated with cardiovascular disease, and in particular play a role in ischemic cardiomyopathy. These data establish a sound basis for preventing, treating or alleviating the symptoms of cardiovascular disease, and in particular ischemic cardiomyopathy, by antagonizing the interaction of 4-1BB and 4-1BB-L. Furthermore, these results demonstrate that antagonizing 4-1BB-L:4-1BB interactions reduces Adriamycin®-induced cardiotoxicity. Therefore, 4-1BB, CD30 and/or OX40 antagonists, may be used prior to or in combination with chemotherapeutic compositions in order to reduce the cardiotoxic side-effects of such chemotherapeutics.

#### EXAMPLE 8

4-1BB IS EXPRESSED BY DAMAGED CARDIAC INTERSTITIAL CELLS AND 4-1BB/4-1BBL SIGNALING CONTRIBUTES TO ADRIAMYCIN®-INDUCED CARDIOMYOPATHY IN MICE.

Co-stimulatory pathways have been implicated in myocarditis and dilated cardiomyopathy in mice and humans. Expression of co-stimulatory ligands is increased on cardiac myocytes, while the receptors are expressed on infiltrating immune/inflammatory cells (Seko et al, 2002; Seko et al, 2001; Seko et al, 1998). The aim of these studies was to determine the role of the 4-1BB/4-1BBL co-stimulatory pathway in the onset and progression of Adriamycin®-induced cardiomyopathy, which is not associated with the extensive inflammatory infiltrate seen with other forms of dilated cardiomyopathy. These studies demonstrate a role for the 4-1BB/4-1BBL immune co-stimulatory pathway in Adriamycin®-induced cardiomyopathy, demonstrated a novel cardiac expression pattern of 4-1BB and implicated apoptosis as a mechanism of co-stimulatory contribution to Adriamycin®-induced cardiomyopathy.

1. *4-1BB and 4-1BBL expression is up-regulated in Adriamycin®-treated myocardium.*

Six-week old C57Bl/6 mice were injected retroorbitally with 45mg/kg Adriamycin® and the hearts were collected at 0, 24, 48, 72, and 96 hrs post treatment. Immunohistochemical staining on cryo-sections for CD45 was performed to detect inflammatory infiltrate, as well as staining for 4-1BB. Immunohistochemistry of CD45 did not recognize positive cells in Adriamycin®-treated myocardium. As positive control, CD45 positive cells were detected in spleen. While no inflammatory infiltrate was observed in the Adriamycin®-cardiomyopathy, we found expression of 4-1BB induced on 1-5% of cardiac interstitial cells within 2 days after Adriamycin® administration. As a percentage of animals demonstrating 4-1BB positive cells, 50% mice were positive for 4-1BB in myocardium at 48 hrs and 75% at 72 hrs. In immunohistochemical analysis, 4-1BBL increased in positivity after Adriamycin® treatment. Leukocyte counts in wild type and 4-1BBL<sup>-/-</sup> demonstrated similar level of neutrophils, monocytes and lymphocytes in peripheral blood, indicating the improvement of cardiac function by loss of 4-1BBL is unrelated to hematopoietic and inflammatory changes.

## 2. *Treatment with Agonistic anti-4-1BB Antibody (M6) Accelerated Cardiac Dysfunction and m4-1BB-Fc Delayed and Reduced Cardiac Dysfunction.*

An agonistic antibody to 4-1BB (M6) accelerated and exacerbated cardiac dysfunction in an Adriamycin® challenge model. In contrast, m4-1BB-Fc, which is a soluble decoy receptor for 4-1BBL, delayed and reduced cardiac dysfunction.

100 ug/mouse of agonistic antibody to 4-1BB (M6, lot 9159-069 from Amgen Hybrodima Group) was administered IP on days 0, 3 and 6. Day 0 being the date of Adriamycin® challenge. NaCl controls were included for each treatment regimen. Wild type (WT), 4-1BBL KO, or WT mice treated with an activating antibody to 4-1BB (M6) were challenged with Adriamycin® in doses ranging from 22.5 to 45 mg/kg by retroorbital injection, immediately following baseline echocardiographic (ECHO) analysis of cardiac function. Serial ECHO analysis was performed at 1, 2.5 and/or 5 weeks after Adriamycin® challenge. In one study, WT and 4-1BBL KO mice were challenged with Adriamycin® (45mg/kg) and hearts were collected at 24, 48 and 72 hours. TUNEL positivity by IHC and caspase 3 activation by western blot were determined as indices of apoptosis. 4-1BBL KO mice had improved cardiovascular function and decreased penetrance of cardiomyopathy, as evaluated by M-mode echocardiography compared to WT controls (see Table 4, below and Figure 10). For Table 4, combination of stroke volume, systolic, diastolic end volume was used to categorize functional phenotype. 4-1BBL KO mice have reduced cardiotoxicity and improved function post-Adriamycin®. Treatment of WT C57Bl/6 mice with the 4-1BB activating antibody (M6) accelerated the onset of ADR-induced cardiomyopathy (Figure 11).

Table 4.

Phenotype	WT	4-1BB <sup>-/-</sup> KO	M6 antibody	M4-1BB-Fc
Normal	48%	79%	53%	70%
Dysfunction	52%	21%	47%	30%

3. *Apoptosis was increased in adriamycin myocardium.*

C57Bl/6 mice were treated with 45mg/kg adriamycin. Heart tissues were harvested at different time points and analyzed for TUNEL positive nuclei. TUNEL positivity increased at 48 hrs and peaked at 72 hrs. Whole heart digests were collected from Adriamycin®-treated mice were stained with troponin-I(TnI) antibody and FITC conjugated secondary antibody and propidium iodide. TnI positive cells were analyzed for sub-G1 DNA fragments. In WT mice, cardiac TUNEL positivity increased at 48 and 72 hr after Adriamycin® injection.

Cardiac apoptosis, measured by TUNEL and sub-G1 DNA, was increased 3 days after Adriamycin®, concomitant with the increased expression of 4-1BB on interstitial cells. Chronic ongoing apoptosis, determined 5 weeks after Adriamycin® challenge when cardiac dysfunction is maximal in wild type but largely absent in 4-1BBL<sup>-/-</sup> mice, was lower in 4-1BBL<sup>-/-</sup> mice (1.5-fold vs baseline), compared to WT mice (4 fold). In a separate study, caspase 3 activation, determined by Western blot, was increased at 48 to 72 hrs post-Adriamycin® (45mg/kg). In contrast, Adriamycin® did not induce caspase 3 cleavage in 4-1BBL<sup>-/-</sup> myocardium. Determined by western blot, Adriamycin® reduced phosphorylation of Akt in wild type but not 4-1BBL<sup>-/-</sup> hearts. Phosphorylation of JNK and p38 was not impacted by Adriamycin®. Therefore, 4-1BB/4-1BBL immune co-stimulatory pathway contributes to Adriamycin®-induced cardiomyopathy, possibly through modulation of Akt signaling to regulate

In conclusion, 4-1BBL deficient mice and 4-1BBL decoy receptor-treated mice conferred partial resistance to adriamycin induced cardiac damage, whereas 4-1BB activating antibody accelerated onset of damage, implying the contribution of 4-1BB to Adriamycin® effects in heart. Apoptosis, measured by TUNEL, sub-G1 DNA and activated caspase-3, was increased in Adriamycin®-treated wild type myocardium, but reduced in 4-1BBL<sup>-/-</sup>. Phosphorylation of Akt was selectively suppressed by Adriamycin®, but maintained by loss of 4-1BBL, indicating the modulation of apoptosis by co-stimulatory pathway in heart is possibly through Akt, but not Jnk and p38 signaling. The consistency of decreased index of apoptosis and the improved cardiac function in 4-1BBL<sup>-/-</sup> suggests apoptosis play a pivotal role in Adriamycin®-induced cardiac deficiency.

EXAMPLE 9  
ANTIBODIES GENERATED AGAINST IL-17, IL-17R, IL-18, IL-18R,  
4-1BB, 4-1BB-L, CD30, CD30-L AND CD39

Monoclonal and/or polyclonal antibodies were generated against IL-17, IL-17R, IL-18, IL-18R, 4-1BB, 4-1BB-L, OX40, CD30, CD30-L and CD39 using standard techniques. One or more of these antibodies, or other antibodies directed against IL-17, IL-17R, IL-18, IL-18R, 4-1BB, 4-1BB-L, OX40, OX40-L, CD30, CD30-L or CD39 may be used as an antagonist for the treatment of cardiovascular disease. Immunogens used to generate antibodies included purified polypeptides, fragment thereof such as the extracellular domain, Fc-fusion proteins of the extracellular domains, and leucine-zipper derivatives of the extracellular domains (refer to Table 3 below). Of course, other forms of the proteins could be used to generate antibodies, such as any immunogenic fragment, alone or fused with other proteins. In addition, DNA encoding a polypeptide can be used as an immunogen, for example, DNA may be given intradermally (Raz et al., 1994, *Proc. Natl. Acad. Sci. USA* 91: 9519) or intamuscularly (Wang et al., 1993, *Proc. Natl. Acad. Sci. USA* 90: 4156); saline has been found to be a suitable diluent for DNA-based antigens, or by other similar techniques, as reviewed by Pardoll and Beckerleg in *Immunity* 3: 165, 1995.

In general, the antibodies were generated by the following method: rodents (BALB/c mice or Lewis rats, for example) were immunized with the polypeptide immunogen emulsified in an adjuvant (such as complete or incomplete Freund's adjuvant, alum, or another adjuvant, such as Ribi adjuvant R700 (Ribi, Hamilton, MT)), and injected in amounts ranging from 10-100 micrograms subcutaneously or intraperitoneally. Ten days to three weeks days later, the immunized animals were boosted with additional immunogen and periodically boosted thereafter on a weekly, biweekly or every third week immunization schedule.

Serum samples were periodically taken by retro-orbital bleeding or tail-tip excision to test for polypeptide-specific antibodies by dot-blot assay, ELISA (enzyme-linked immunosorbent assay), immunoprecipitation, or other suitable assays, such as FACS analysis of antibody binding to its original immunogen. Following detection of an appropriate antibody titer, positive animals were provided one last intravenous injection of respective immunogen in saline. Three to four days later, the animals were sacrificed, spleen cells harvested and fused to a murine myeloma cell line, e.g., NS1 or preferably P3X63Ag8.653 (ATCC CRL-1580). The hybridoma cells were plated in multiple microtiter plates in a HAT (hypoxanthine, aminopterin and thymidine) selective medium to inhibit proliferation of non-fused cells, myeloma hybrids, and spleen cell hybrids.

Positive hybridoma cells were injected intraperitoneally into syngeneic rodents to produce ascites containing high concentrations of monoclonal antibodies. Alternatively, hybridoma cells were grown *in vitro* in flasks or roller bottles by various techniques. Monoclonal antibodies were purified by ammonium sulfate precipitation, followed by gel

exclusion chromatography. Alternatively, affinity chromatography based upon binding of antibody to protein A or protein G has also been used.

Of course other conventional techniques may be used, such as those described in U.S. Patent 4,411,993. For example, the immunogen preparation, choice of adjuvant and immunization protocol are well known in the art and may be found, for example in *Antibodies: A Laboratory Manual*, Harlow and Land (eds.), Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, (1988).

Table 4.

Molecule	Ab name	Immunogen	Species	Type/Isotype
IL-17	mIL-17-M210	mCTLA8-Fc	Rat	mAb
IL-17	mIL-17-P1	mIL-17	Rabbit	polyclonal
IL-17R	hIL-17R-M202	hIL-17R-Fc (cos)	Mouse	IgG2a
IL-17R	hIL-17R-M203	hIL-17R-Fc (cos)	Mouse	IgG1
IL-17R	hIL-17R-M204	hIL-17R-Fc (cos)	Mouse	IgG2a
IL-17R	mIL-17R-M177	mIL-17R-Fc	Rat	IgG2a
IL-17R	mIL-17R-M178	mIL-17R-Fc	Rat	IgG2a
IL-17RH	mIL-17RH-M561	mIL-17RH-Fc	Rat	IgG2a
IL-17RH	mIL-17RH-M561	mIL-17RH-Fc	Rat	IgG2a
IL-18	hIL-1R/AcpL-P1	hIL-1R/AcpL-Fc	Rabbit	Polyclonal
IL-18	mIL-1R/AcpL-P1	mIL-1R/AcpL-Fc	Rabbit	Polyclonal
IL-18R	hIL-18R-M495	hIL-18R	Rat	IgG2b
IL-18R	hIL-18R-M496	hIL-18R	Rat	undetermined
IL-18R	hIL-18R-M497	hIL-18R	Rat	IgG2b
IL-18R	mIL-18R-M375	mRp1-Fc	Rat	IgG1
IL-18R	mIL-18R-M376	mIL-1R/RpL-Fc	Rat	IgG2a
IL-18R	mIL-18R-M377	mIL-1R/RpL-Fc	Rat	IgG1
IL-18R	hIL-18R-P1	h2F1 GST	Rabbit	polyclonal
IL-18R	hIL-18R-P1	sol m2F1	Rabbit	polyclonal
4-1BB	h41BB-M121	h4-1BB-Fc	Mouse	mAb / IgG1
4-1BB	h41BB-M127	h4-1BB-Fc	Mouse	mAb / IgG1
4-1BB	h41BB-M135	h4-1BB-Fc	Mouse	mAb / IgG1
4-1BB	h41BB-M4	sol h4-1BB-Fc	Mouse	mAb / IgM
4-1BB	h41BB-M8	sol h4-1BB-Fc	Mouse	mAb / IgG3
4-1BB	h41BB-M6	sol m4-1BB-Fc	Rat	mAb / IgG2a
4-1BB	m41BB-P1	sol m4-1BB-Fc	Rabbit	polyclonal

4-1BB-L	m41BB-L-M520	m4-1BB-L-leuzip	Rat	mAb / IgG2a
4-1BB-L	m41BB-L-P2	flag m4-1BB-L	Rabbit	polyclonal
CD30	hCD30-M44	hCD30-Fc	Mouse	mAb / IgG1
CD30	hCD30-M67	hCD30-Fc	Mouse	mAb / IgG1
CD30-L	hCD30L-M80	hCD30L-Fc/CV-1	Mouse	mAb / IgG2b
CD30-L	hCD30L-M81	hCD30L-Fc/CV-1	Mouse	mAb / IgG2b
CD30-L	hCD30L-M82	hCD30L(CHO)	Mouse	mAb / IgG2a
CD30-L	mCD30L-M15	mCD30L(CHO)	Rat	mAb / IgG2a
CD30-L	mCD30L-M30	mCD30L(CHO)	Rat	mAb / IgG2a
OX40	mOX40-M5	mOX40-Fc	Rat	IgG1
OX40	mOX40-M6	mOX40-Fc	Rat	IgG2b
CD39	mCD39-M105		Rat	mAb / IgG2a